FISHERY RESOURCES

REGION FOUR

ANADROMOUS FISH IN THE SOUTHEASTERN UNITED STATES AND RECOMMENDATIONS FOR DEVELOPMENT OF A MANAGEMENT PLAN

FISH AND WILDLIFE SERVICE

U.S. DEPARTMENT OF THE INTERIOR

FISHERY RESOURCES

REGION FOUR

ANADROMOUS FISH IN THE SOUTHEASTERN UNITED STATES AND RECOMMENDATIONS FOR DEVELOPMENT OF A MANAGEMENT PLAN

FISH AND WILDLIFE SERVICE

U.S. DEPARTMENT OF THE INTERIOR

ANADROMOUS FISH IN THE SOUTHEASTERN UNITED STATES

AND RECOMMENDATIONS FOR DEVELOPMENT OF A

MANAGEMENT PLAN

by

Roger A. Rulifson[1] and Melvin T. Huish

North Carolina Cooperative Fishery Research Unit
Box 5577 State College Station
4105 Gardner Hall
Raleigh, North Carolina 27607

Contract No. 14-16-0004-80-077

and

Project Officer

Robert W. Thoesen
Anadromous Fisheries Specialist
U.S. Fish and Wildlife Service
Fishery Resources
Richard B. Russell Federal Building
75 Spring Street, S.W.
Atlanta, Georgia 30303

Performed For

U.S. Fish and Wildlife Service
Region 4 Regional Office
Atlanta, Georgia

15 February 1982

[1] Present address: Center of Environmental Sciences, Unity College, Unity, ME 04988.

DISCLAIMER

The opinions, findings, conclusions, or recommendations expressed in this report are those of the authors and are based in part on a questionnaire completed by personnel of southeastern State and Federal agencies and are not necessarily the views of Fishery Resources, Fish and Wildlife Service, U.S. Department of the Interior, nor does mention of trade names or commercial products constitute endorsement or recommendation for use by the Federal Government.

Suggestions or questions regarding this report should be directed to:

Fishery Resources
U.S. Fish and Wildlife Service
Richard B. Russell Federal Building
75 Spring Street, S.W., Room 1258
Atlanta, Georgia 30303
(404) 221-3576
FTS 242-3576

This report should be cited as follows:

Rulifson, R.A., M.T. Huish and R.W. Thoesen. 1982. Anadromous fish in the Southeastern United States and recommendations for development of a management plan. U.S. Fish and Wildlife Service, Fishery Resources, Region 4, Atlanta, GA, 525 p.

PREFACE

Anadromous fish of the southeastern Atlantic and Gulf coasts are extremely valuable to the Nation. However, major declines have occurred to stocks of these commercially and recreationally important species and to other anadromous species as well. Previously, no efforts were made to summarize the state of knowledge about these fish or what management efforts are being conducted for the entire Southeastern United States. Thus, based on the information collected for this report, a proposed plan is presented which could lead to protection and restoration of these resources. The report includes a summary of biological information and points out some areas for which no information exists. It also presents recommendations developed by several Federal and State personnel for incorporation into a mangement plan. Based on the history of these resources, action will be required if their further decline is to be prevented.

EXECUTIVE SUMMARY

GENERAL: Anadromous fish in southern waters may migrate within and between State and Federal jurisdictional units. They have been, and potentially are, of immense economic importance to the United States. Some members are extirpated from portions of their former ranges, some are nearly extinct, and declines are continuing.

FINDINGS: Plans for restoration and protection of anadromous fish stocks throughout the Southeast are either non-existent or fragmented. In addition, efforts to arrest declines of these fish are uncoordinated. Since many of the problems are similar in several rivers, estuaries, and the continental shelf, it is recommended that planning committees involving appropriate jurisdictional groups be established. Based upon their conclusions, plans incorporating economic, social, and biological components should be developed for managing the stocks. This document outlines a potential administrative structure, and recommends biological studies and establishment of appropriate facilities. It also recommends that close working relationships be established between State, Federal, and user groups.

The data and materials of this report will be valuable for developing detailed plans for managing anadromous fish stocks in Southeast U.S. waters.

AVAILABILITY: The report, which summarizes information regarding the biology and current management of anadromous fish in the Southeast, is available from:

Fishery Resources
U.S. Fish and Wildlife Service
Richard B. Russell Federal Building
75 Spring Street, S.W., Room 1258
Atlanta, Georgia 30303

Submitted in fulfillment of Contract Number 14-16-0004-80-007 by the North Carolina Cooperative Fishery Research Unit under the sponsorship of the U.S. Fish and Wildlife Service. Work was completed 30 June 1981.

TABLE OF CONTENTS

* No information available; therefore, these sections were not completed.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the efforts of numerous people for preparation of this report. James McCann, James Clugston, William Newman, Joseph Boccardy, and Louis Villanova of the U.S. Fish and Wildlife Service were very helpful for much of the technical material. Frank Richardson, Assistant Regional Director, U.S. Fish and Wildlife Service, Atlanta, deserves special recognition for his assistance and support in publication of this document.

Of particular value were the efforts by numerous officials of State conservation agencies in the South. Without their support much of the information would not have been available. Representatives of the National Marine Fisheries Service also contributed materially to the efforts.

Dr. R.G. Hodson, Susan Lingg, Norman Walker, Allyson Robertson Boyette, Tony Howell, Margaret Pressley, Tillie Laws, Gayle Rulifson, and Karin Sousa performed a variety of services associated with assembling and typing the material.

The work was accomplished under the supervision of the North Carolina Cooperative Fishery Research Unit, which is supported jointly by North Carolina State University, North Carolina Wildlife Resources Commission, and the Fish and Wildlife Service, U.S. Department of the Interior.

OVERVIEW

From the time early Americans wrestled with 100 pound sturgeons and colonial days when George Washington supervised shad fishing on his plantation until the present time, anadromous fish have been economically, recreationally, and culturally valuable resources for our Nation. However, we have not provided the stewardship necessary to prevent stock decline, which, in some cases, has brought them to near extinction. Overfishing, development of water resources, poorly defined or conflicting jurisdictions, and other factors have all contributed to the decline of anadromous stocks. This condition cannot be reversed easily since adequate data and experience does not exist to serve as a base for in-depth management programs.

This document is one of the first efforts to develop a plan for strengthening the efforts of numerous southern State, university, and Federal agencies that are presently participating in restoration activities for several anadromous species. With the exception of striped bass, previous restoration efforts have been non-existent, fragmented, or with short-term objectives. In addition, evaluation of these programs has not been suitable due to lack of mutual goals and exchange of information.

The following document presents information about State and Federal programs concerned with managing anadromous fishes of Southeastern waters, major problems of anadromous fisheries, surveys of current biological knowledge, perceptions of State representatives about the problems and their programs, and suggestions for developing a plan for managing these resources on a regional as well as river system basis.

A plan encompassing the wide spectrum of information and activities is needed if all the anadromous resources are to be considered rather than those selected based on current publicity, economic, or recreational value. Plans and budgets for past and current efforts have often lacked a broad or regional approach. Thus, the complex ecological relationships associated with migration and intertwined life histories have often been ignored. Also, anadromous fishery programs in the South have concentrated on the striped bass and have not considered many of the other species. If progress is to be made on a scale great enough to reverse the decline of these resources, research, management, regulatory, and user groups must express a greater unity in their efforts.

Major Fishery Problems

A decline in the condition of the Nation's fishery resources has occurred as the result of increased sport and commercial fishing and environmentally-degrading land and development activities.

Following is a list of some factors which affect the condition of the fishery resources in the United States:

- --angler population growing at the rate of about six percent annually;
- --demand for fish as a food source increasing at a rate slightly higher than the total United States population increase;
- --loss of spawning and other necessary fish habitat due to erosion, dredging, filling, channelization, and dam construction;
- --chlorine discharges;
- --industrial pollution, including heated water effluents;
- --agricultural pollution, including herbicides and pesticides;
- --increased water-oriented recreational activities;
- --introduction of competitive exotic species;
- --increased demand for water by municipalities, manufacturing, irrigation, power generation, mining, and others;
- --oil and gas development.

Further impact of these factors will be appreciable unless action is taken to protect the fishery resources.

Some fish species can tolerate a wide range of chemical and physical conditions and are therefore highly adaptable to a variety of situations; however, they are not necessarily desirable (e.g., carp). Many of the more desirable sport and commercial species are not capable of such adaptation and now require major efforts to restore them if they are to survive. Such efforts will require the expertise of many fishery managers, fishery researchers, and specialized facilities.

Anadromous Fishes of the South Atlantic and Gulf Coasts

Urbanization, industrialization, and agricultural expansion are progressively increasing environmental pressures on the valuable aquatic resources of this area. The result has been a decline in the coastal and anadromous fish populations in waters along the South Atlantic and Gulf coasts (striped bass; American, Alabama, and hickory shads; Atlantic and shortnose sturgeons; blueback and skipjack herrings). In some areas, commercial catches have declined more than 60% in recent years. Reduction in the sport fishery catch has also occurred. The need to accelerate and

expand programs to improve these anadromous fish resources and their habitats in Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, and South Carolina has been formally recognized as an Important Resource Problem (IRP) by the U.S. Fish and Wildlife Service. The IRP designation is detailed in Section 1.3 of this document.

In a survey conducted in 1975, striped bass were found to be second only to salmon in the category of sea-run fish sought by anglers. However, striped bass stocks along the South Atlantic coast are smaller historically but are decreasing steadily. On the Gulf coast, local races or strains of striped bass have been reduced drastically or lost entirely. With the exception of the northern half of North Carolina, southeastern striped bass do not exhibit the same migratory patterns as northeastern striped bass. Rather southeastern stocks usually consist of local races that utilize one or a few rivers and a connecting estuary. These stocks apparently have little exchange of individuals between populations. For this reason, pollution or other barriers such as dams have long-term impacts on the fisheries. Stocking efforts to restore runs were initially unsuccessful, but now several State programs are moderately successful in reestablishing coastal populations. However, opportunities for reestablishing or enhancing important anadromous species are inhibited by the interstate complexity of major river systems and lack of a broad approach to stock management.

Although the technology exists for rearing and stocking striped bass, there is a lack of information as to precisely why, in spite of stocking, some populations have disappeared. Thus, research is needed to determine the critical factors that control population levels and limit recovery of historically-indigenous species to acceptable levels, and to provide information about how to supplement stocks more effectively through hatchery production.

There is also a need for estuarine research to determine the changes in habitat most critical to estuarine fish stocks, causes of stock decline, the interactions and relationships among the various species that inhabit estuaries, and methods for stock enhancement. Numerous studies since 1965 have called attention to serious estuarine problems and the their impacts on fishery resources Changes in the estuarine environment continue at a rapid pace and these changes appear to have numerable effects on stocks of fish and shellfish. However, the effects have seldom been documented carefully, nor have cause-and-effect relationships been established. Some of this work is presently being conducted at the State, university, and Federal level; however, it is only a start.

All coastal states in the Southeast have an anadromous program which may vary depending on the importance of the resource and the political emphasis placed on the fishery. These programs in the past have received varying support from Federal grants.

Synopsis of Anadromous Fish Conservation Act

Enactment of Public Law 89-304 on 30 October 1965 reflected the concern of Congress for the decline of anadromous fish stocks and recognized the need to strengthen and expand programs being conducted with limited State financial capabilities. Funding began Fiscal Year 1967, and the Federal Government and States launched a coordinated program to conserve, develop, and enhance the anadromous fish resources of the Nation, including populations in the Great Lakes that ascend streams to spawn. The Act authorized Federal appropriations not to exceed $25 million for the period ending 30 June 1970 to finance projects on a 50% matching basis.

On 14 May 1970 Public Law 91-249 amended the Anadromous Fish Conservation Act, extending it four years to 30 June 1974. Appropriation of an additional $32 million was authorized. The extension provided that the Federal share be increased to a maximum of 60% whenever two or more States, which have a common interest in a basin, undertake a joint project. From its start until 3 October 1970 the program was administered jointly by the Bureaus of Sport Fisheries and Wildlife and Commercial Fisheries, U.S. Department of the Interior. Since that date, administrative duties have been the responsibility of the National Marine Fisheries Service, U.S. Department of Commerce, and the Fish and Wildlife Service, U.S. Department of the Interior.

On 30 July 1974, the Act was amended by Public Law 93-362, which extended it to 30 June 1979. This law provided that the Federal share be increased to a maximum of 66 2/3% whenever two or more States having a common interest jointly undertake a project. Appropriation of an additional $25 million was also authorized.

The current law, Public Law 96-118, expires at the end of Fiscal Year 1982 and authorizes an additional $39 million for program expenditures plus $4.75 million for a special striped bass study to be undertaken from Maine to North Carolina.

State Anadromous Fish Conservation Act Programs

Louisiana has a five-year Anadromous Fish Conservation Act project with the U.S. Fish and Wildlife Service to reestablish striped bass populations in the coastal waters of Louisiana.

Total project costs are $200,000, half of which will be paid by the U.S. Fish and Wildlife Service and half by the Louisiana Wildlife and Fisheries Commission. The main objective of this project is to rear and release striped bass fingerlings into coastal waters. In past years, different strains were released into separate river systems.

Mississippi has a three-year Anadromous Fish Conservation Act project with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service to reestablish a striped bass fishery in coastal Mississippi. Total project costs are $285,000, half of which will be paid by the Mississippi Bureau of Marine Resources and half by the Federal Government (shared equally by the U.S. Fish and Wildlife Service and National Marine Fisheries Service). Objectives of this project are to rear striped bass fingerlings for release into the St. Louis and Biloxi Bay systems, and evaluate the success of these releases. The reestablishment of a viable striped bass population in coastal Mississippi waters requires more than this project is capable of providing. Therefore, the State will receive 250,000 fingerlings annually from the National Fish Hatchery System under cooperative agreement.

Alabama has a three-year Act project with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service to reestablish a striped bass fishery in coastal Alabama waters. Total project costs are $282,000, half of which is paid by the Marine Resources Division; the rest is shared equally by the two Federal agencies. Project objectives are to rear striped bass fingerlings for release into the Mobile and Perdido Bay systems, and evaluate the success of these releases. Reestablishment of a viable striped bass population in coastal Alabama waters requires more than this Grant-in-aid project is capable of providing, so the State receives an additional 250,000 fingerlings annually from the National Fish Hatchery System under cooperative agreement.

Louisiana, Mississippi, and Alabama have been successful in establishing striped bass populations in coastal waters and now are hoping to find evidence of natural reproduction. These States traditionally have stocked a strain of stripers from Moncks Corner, South Carolina, and occasionally a more northern strain when available. At present, these States desire to obtain additional fingerlings that demonstrate stronger anadromous tendencies such as those strains found in Chesapeake Bay and the Hudson River.

These three States also have been receptive to the efforts by the U.S. Fish and Wildlife Service to reestablish the Gulf coast race of striped bass to waters within its historic range. During November 1980, 12,500 six-to eight-inch-long Gulf race stripers were stocked in the Pascagoula River, Mississippi, and 100 six-to eight-inch fish were stocked in the Sabine National Wildlife Refuge, Louisiana, by the U.S. Fish and Wildlife Service.

In 1981, a prolonged drought caused the pool on the Sabine National Wildlife Refuge to nearly dry up and undoubtably resulted in mortality of the Gulf race striped bass stocked there (G.L. Hickman 1981, pers. comm.).

Florida and Georgia have utilized Anadromous Fish Conservation Act funds in the past but do not now have active projects. These two States have also been receptive to the reestablishment of Gulf race striped bass in their waters. During June 1980, the U.S. Fish and Wildlife Service stocked 100,800 two-to three-inch Gulf race fingerlings in the Flint River, Bainbridge, Georgia, and Lake Seminole, Georgia. In addition 12,500 six-to eight-inch Gulf race stripers were stocked in the Apalachicola River, Florida.

The South Carolina Wildlife and Marine Resources Department has three Federal Aid projects with the Fish and Wildlife Service under the Anadromous Fish Conservation Act. One project is a comprehensive "before and after" study of the Santee-Cooper Rediversion Project with emphasis on migratory species. Currently, the project focuses on blueback herring movements through Pinopolis Lock and Dam and estimates the magnitude of the fishery for this species. Other studies involve a creel census, relative abundance, distribution, and seasonal movements of juvenile anadromous fishes, and studies to determine age, growth rates, and year class composition of anadromous plus selected resident fishes in the Santee and Cooper Rivers. The U.S. Fish and Wildlife Service share of project costs is about $41,000 per year. The second project is a five-year study to enhance the striped bass population in the Santee River to ensure adequate stock availability following rediversion. Total cost is $544,000 equally shared by the State and the U.S. Fish and Wildlife Service. The study requires an additional 60,000 advanced-size striped bass fingerlings from the National Fish Hatchery System in order to stock in quantities sufficient for a statistically valid evaluation. The third study is a five-year project concerning the life history, ecology, culture, and management of Atlantic sturgeon. Total project costs are $310,000 equally shared by the Marine Resources Division and U.S. Fish and Wildlife Service. The sturgeon work is greatly dependent upon the Orangeburg National Fish Hatchery and is covered under a cooperative agreement. Current emphasis concerns propagation and enhancement techniques.

North Carolina has two Conservation Act projects with the U.S. Fish and Wildlife Service. The first is a five-year research assessment study of Albemarle Sound - Roanoke River striped bass conducted cooperatively by the Department of Natural Resources and Community Development, Division of Marine Fisheries; the Wildlife Resources Commission, Division of Inland Fisheries; and North Carolina State University. Collectively, the data provide information on spawning and nursery areas, egg production

and viability, commercial and recreational harvests, age and size composition of fish harvested, size of the spawning population, and relative annual abundance of young fish. Total project costs are $325,376 shared equally between the State and the U.S. Fish and Wildlife Service. The second project is a three-year coastwide anadromous fisheries management project that encompasses all anadromous species in all coastal and offshore North Carolina waters. Project costs are $725,000 shared on an equal basis with the National Marine Fisheries Service. Project emphasis is to locate spawning and nursery areas and to determine growth, abundance, age, species, size, sex ratio, migration, distribution, and harvest of all anadromous fish. The project also involves experimental stocking of striped bass in an attempt to enhance dwindling natural populations. The stocking program is entirely dependent upon receiving advanced fingerling fish from the National Fish Hatchery System under cooperative agreement.

1. GOALS, OBJECTIVES, IMPORTANT RESOURCE PROBLEMS, AND METHODS

An indexing system was used in this document to present the variety of information about southern anadromous species and the State and Federal programs that involve anadromous stocks. The section entitled "Overview" presents material concerning the major fishery problems confronting Southern States and summarizes the Fish Conservation Acts that have been written in attempts to correct the problems. This report also contains six subject sections, Literature Cited, and Appendices. Section 1 deals with the goals, objectives, and background of the U.S. Fish and Wildlife Service activities that involve Southeast anadromous species. Section 2 presents the research and management activities that are supported by Federal funds. Section 3 is an extensive summary of biological information, management systems, and action programs for all anadromous species in southeastern waters. Section 4 comprises a narrative summary of the responses by eight Southern States to a questionnaire and their assessment of State anadromous fish problems. Section 5 identifies research needs of the States and Federal Government, and Section 6 presents recommendations for management of southern anadromous fish stocks.

1.1 Fish and Wildlife Service Mission Statement

The mission of the Fish and Wildlife Service is to "Provide the Federal leadership to conserve, protect, and enhance fish and wildlife and their habitat for continuing benefit to the people."

1.2 Goals and Objectives

1.2.1 Fish and Wildlife Service Fisheries Goal

The goal of the U.S. Fish and Wildlife Service is to promote the conservation and management of the Nation's freshwater and anadromous fish populations for the benefit of the people.

1.2.2 Anadromous Species Goals and Objectives

Goal No. 1

To provide national leadership in the development of integrated, comprehensive, cost effective resource plans for the Nation's freshwater and anadromous fish populations.

Objective No. 1 Submit by 15 February 1982 recommendations for an anadromous fish plan for the Southeast. The document should summarize the history of restoration efforts, the cooperation within the Service and the States, and the potential for successes with various species, rivers, and levels of effort.

This planning effort is not intended to infringe on the management prerogatives of the States, but is intended to complement their activities.

Objective No. 2 Help determine the status of anadromous populations and angler demand in the South Atlantic and Gulf of Mexico regions and develop interagency plans for the major river and estuarine systems involved.

Goal No. 2

Provide for the implementation of plans that have been developed and proceed with those programs that have been mandated by legislation or inter/intra-agency agreements.

Objective No. 1 Restore South Atlantic and Gulf of Mexico anadromous fish populations to suitable historic habitats in accordance with approved restoration plans.

Objective No. 2 Establish self-sustaining populations of anadromous species in three South Atlantic and Gulf State river systems in cooperation with the States and National Marine Fisheries Service.

Objective No. 3 In cooperation with South Atlantic and Gulf coast States and other Federal agencies, restore striped bass populations to historic levels as defined by the Service and the States.

1.3 Fish and Wildlife Service Viewpoint

1.3.1 Fish and Wildlife Statement of Important Resource Problems (IRPs)

The Important Resource Problem (IRP) system is designed to promote a greater understanding of important fish and wildlife resources and identify where these problems are most acute. IRPs are used as planning tools for the development of many of the goals and objectives contained in the Service Program Management Documents. But IRPs do not replace administrative priorities, budget decisions, or management latitude. They serve as a guide for focusing resource management efforts on species and habitat-related issues of the greatest importance. It should be recognized that ranks assigned to IRPs do not necessarily correspond to budget priorities. All ongoing activities in the Service compete for dollars and personnel every year through the budget process by outlining needs and proposing additional funding and personnel to help address resource concerns. In this competitive process, it must be demonstrated that an IRP is more pressing than another activity for it to

receive additional dollars or personnel. Other ongoing responsibilities or national issues are evaluated along with IRPs to determine their relative importance to fishery research needs.

For a number of years the Service has been operating - and setting priorities - on the basis of some scientific criteria. For example, among the highest priorities of the Service is endangered species and habitat preservation. There is also concern about anadromous fishery resources, particularly those having international implications. In addition, migratory birds have long been one of the key concerns of the Service.

Recently the Service has looked at ways to refine the understanding of these priorities. Where (geographically) are the needs of fish and wildlife resources the greatest? Are some of the problems of greater concern than others, perhaps because of an imminent threat or a particular stress on the environment? These and other questions have challenged Service managers, particularly when it is necessary to determine where available money and personnel should be utilized.

A basic scheme for developing an understanding of important resources, and an identification of where these problems are most acute, has been developed and tested by the Service. The scheme identifies Important Resource Problems, which are defined as those fish and wildlife resources having significant problems in specific geographic areas. The Service, using a series of ranking factors and relative weights of importance, identifies and assigns priorities to IRPs. The key ranking factors include: a) current status of populations; b) current status of habitats (of target species); c) U.S. Fish and Wildlife Service responsibilities for protection, management, or restoration of the resource; d) resource value to humans (e.g., recreational or commercial benefits); e) magnitude of potential loss; f) imminence of threat; and g) desired objective for the IRP (i.e., desired quantity or quality of species populations or human use levels).

The system that was developed for national ranking of Important Resource Problems is a two-page iteration involving first an objective numerical scoring system and then a subjective, intuitive "best professional judgement" system. Imperfections in the process are recognized and future efforts will improve the validity and precision of the work (there will be continuing reviews and updates of the list, which will be used as one basis for revising the Service Management Plan and Program Management Documents).

1.3.2 Important Resource Problems Concerning Anadromous Fishes

1.3.2.1 Title and National Ranking

Estuarine and Anadromous Fish - North Carolina, South Carolina, Florida, Georgia, Alabama, Louisiana, and Mississippi.

National Priority Ranking Number 49 out of 78 for the U.S. Fish and Wildlife Service.

1.3.2.2 Overall Status of IRP

Populations of anadromous and estuarine fish species continue to decline due to habitat destruction, environmental contaminants, hydro-electric operations, and overfishing. A major effort to protect and restore target species is the initiation of the Apalachicola River Phased Environmental Assessment. Greater efforts will be made to restore target species with the development of the Response Plan for this IRP and completion of the Management Plan by the end of Fiscal Year 1981. Cooperative agreements with individual States to continue selected projects are extended through FY 1982 and 1983. Significant highlights include the acquisition of the EPA Bears Bluff Laboratory as a hatchery for striped bass, Atlantic sturgeon, and shad.

Cooperative efforts between the Fish and Wildlife Service and the South Carolina Marine Research Institute have resulted in the spawning of Atlantic sturgeon and the holding of fingerlings at Orangeburg National Fish Hatchery, South Carolina, and the Bears Bluff substation. Future purchases of coastal habitat as wildlife refuges will provide protection of significant spawning and rearing habitats for estuarine species.

1.3.2.3 Restoration of Gulf Race Striped Bass

The Panama City Office of Fishery Assistance, in cooperation with the Welaka National Fish Hatchery, Florida staff, was successful in spawning a Gulf race striped bass (STB-G) female on 2 May 1980. Approximately 400,000 healthy fry were obtained. Fry have been placed in four national fish hatcheries for future broodstock. In an effort toward restoration of this species in riverine habitats, fish were stocked in Florida, Georgia, Alabama, and Louisiana waters. STB-G fry were also transferred to the Cooperative Fishery Research Unit at Auburn, Alabama, and the Alabama Department of Conservation and Natural Resources for

research purposes. During May 1981 a cooperative State of Alabama - Fish and Wildlife Service effort produced healthy fry by spawning an Apalachicola River Gulf race (STB-G) male with an Alabama River STB-G female. The Gulf Race Striped Bass Management Plan is presented in detail in Section 3.2.13.

1.4 Methodologies

1.4.1 Development of Historical Perspective

A historical background detailing socio-economic importance and life history aspects of all anadromous fish species within South Atlantic and Gulf coast waters was compiled by review of published literature, Federal and State project reports, memoranda, and verbal communications. Computerized searches of published literature and Federal-State project reports were conducted specifically for completion of this document by the Library Reference Service, U.S. Fish and Wildlife Service, Denver, Colorado, and by Computerized Search Service, Natural Resources Library, Research Services Branch, Washington, D.C. Additional information was obtained through journals that abstract published manuscripts (e.g., Sport Fishery Abstracts). Many State reports were obtained from various sources, particularly through positive responses to our requests from State agencies. Federal Aid and Dingell-Johnson reports and memoranda were obtained through files located in the Region 4 office, U.S. Fish and Wildlife Service, Atlanta, Georgia.

The enormous bibliography generated by these efforts precluded a thorough review of all information. Therefore, the historical perspectives and life history aspects of anadromous fishes, although extensive, are incomplete. Much of the life history information presented in Section 3 (Description of Anadromous Resources) consists of direct quotations or opinions and conclusions of investigators and does not necessarily reflect the position or opinions of the U.S. Fish and Wildlife Service.

1.4.2 Development of Questionnaire

A questionnaire was developed to address the present status of, management practices for, and attitudes toward anadromous species in Texas and in each coastal State within Region 4. Questions and format were reviewed and critiqued by several State and Federal agencies before the final questionnaire was completed. Mr. Don Baker of the North Carolina Wildlife Resources Commission, Mr. Michael W. Street of the North Carolina Division of Marine Fisheries, Messrs. Lou Villanova and Gladney Davidson of Federal Assistance (U.S. Fish and Wildlife Service), and others gave valuable criticisms and recommendations for improving the draft.

A total of 17 questionnaires was sent to the freshwater and marine divisions of each State fisheries agency within Region 4 and Texas, the Regional Office of the National Marine Fisheries Service (NMFS) at Tampa-St. Petersburg, Florida, and the NMFS Laboratory at Beaufort, North Carolina.

The questionnaire included the non-anadromous striped bass x white bass hybrid to compile stocking information and to give an opportunity for comments.

1.4.3 Identification and Evaluation of River Systems

A portion of the questionnaire was designed to allow State agencies to identify the river systems within or bordering their State that are important to anadromous fish (Fig. 1). The marine and freshwater representatives of each State agency were then asked to evaluate the condition of each river system by indicating the relative importance of 21 physical and chemical disturbances that may affect anadromous fish stocks inhabiting the river. The following rivers and areas within Region 4 were identified through State responses and are illustrated in Figure 1 with the following numeric designations:

NORTH CAROLINA - Currituck Sound (1), Albemarle Sound (2), and the North (3), Pasquotank (4), Little (5), Perquimans (6), Yeopim (7), Chowan (8), Meherrin (9), Roanoke (10), Cashie (11), Scuppernong (12), Alligator (13), Pungo (14), Pamlico (15), Tar (16), Neuse (17), Trent (18), North (19), Newport (20), White Oak (21), New (22), Cape Fear (23), Northeast Cape Fear (24), Black (25), and Pee Dee (26) Rivers.

SOUTH CAROLINA - Waccamaw (27), Little Pee Dee (28), Great Pee Dee (26), Black (29), Santee (30), Cooper (31), Ashley (32), Edisto (33), Ashepoo (34), Combahee (35), Sampit (36), Salkehatchie (37), Savannah (38), and Lynches (39) Rivers.

GEORGIA - Savannah (38), Ogeechee (40), Altamaha (41), Oconee (42), Satilla (43), Ocmulgee (44), Chattahoochee (51), and Flint (52) Rivers.

FLORIDA - St. Marys (45), Nassau (46), St. Johns (47), Tomoka (50), Hillsborough (53), Suwannee (54), Apalachicola (55), Ocklockonee (56), and Escambia (57) Rivers; Pellicer (48) and Moultrie (49) Creeks.

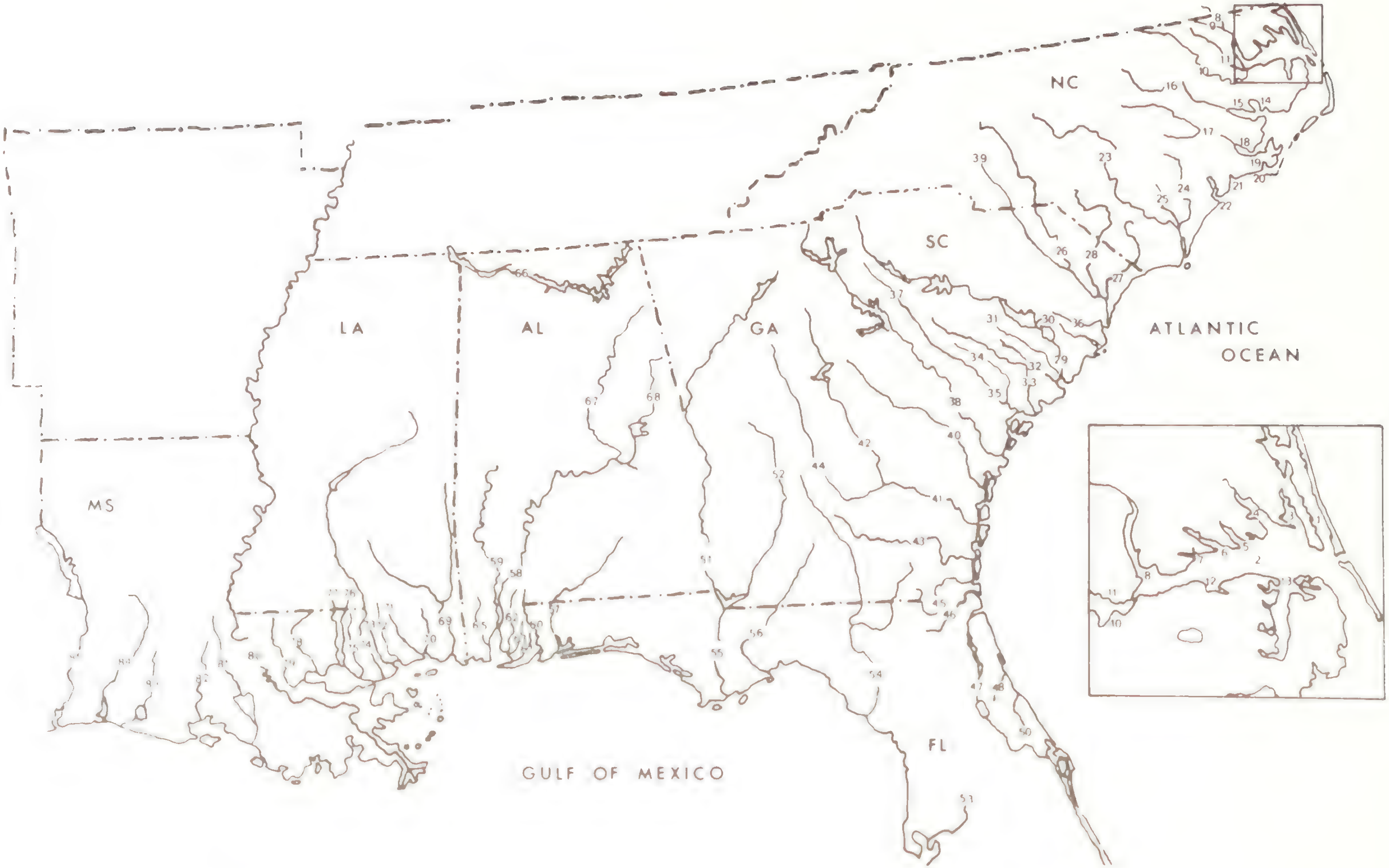


Figure 1. Riverine areas within Region 4 that were identified by State and Federal agencies as containing stocks of anadromous fishes.

ALABAMA - Alabama (58), Tombigbee (59), Perdido (60), Bon Secour (61), Fish (62), Magnolia (63), Dog (64), Fowl (65), Tennessee (66), Chattahoochee (51), Coosa (67), and Tallapoosa (68) Rivers.

MISSISSIPPI - Pascagoula (69), Tchouticabouffa (70), Biloxi (71), Wolf (72), Jourdan (73), and Pearl (74) Rivers.

LOUISIANA - Pearl (74), Bayou LaCombe (75), Tchefuncte (76), Tangipahoa (77), Tickfaw (78), Amite (79), Mississippi (80), Atchafalaya (81), Vermillion (82), Mermentau (83), Calcasieu (84), and Sabine (85) Rivers.

Several important river systems were omitted in response by the State representatives. Discussion of river system status is presented in Section 4 (Questionnaire Summary) of this document.

1.4.4 Review of Research Needs

Several methods were used to obtain information concerning ongoing research, present management activities, and future research needs of various State, Federal, university, and other agencies. Questionnaire responses by marine and freshwater representatives of each State agency were used to identify present and proposed management activities for anadromous stocks in waters of South Atlantic and Gulf coast States. Each representative also listed future research needs for his State. These, along with present activities and future needs of the U.S. Fish and Wildlife Service, were reviewed and discussed by personnel from the Service and the North Carolina Cooperative Fishery Research Unit, North Carolina State University, in meetings held during 1-3 June 1981 at the National Fishery Research Laboratory, Gainesville, Florida.

The Gainesville meeting produced a series of recommendations on initiating cooperative research efforts to assess and manage anadromous resources in waters of South Atlantic and Gulf coast States. These recommendations, along with suggestions for management practices, are presented in Section 6 (Recommendations).

Little information was obtained concerning ongoing and proposed anadromous research at university and private facilities that have not been funded by Federal Grant programs. A notice requesting information concerning anadromous research at institutions and private agencies appeared in the May-June issue of Fisheries, a publication of the American Fisheries Society. No information was obtained as a result of this notice prior to finalizing this document.

State and Federal activities and ongoing research are discussed in Section 2 (Ongoing Research and Management Activities), and the anticipated research needs are presented in Section 5 (Identified Research Needs). It should be noted that many of the research needs and activities suggested by a State may be applicable to other States and the U.S. Fish and Wildlife Service research activities and proposals may apply to one or several States.

2. RESEARCH AND MANAGEMENT ACTIVITIES

2.1 State Anadromous Fish Conservation Act Programs

Following is a listing of State research projects aided by Federal funds. The letters below are used in project numbers:

C National Marine Fisheries Service
S Fish and Wildlife Service
A Anadromous Project
F Fisheries

Each project is identified with one or several of the letters listed above, followed by the project number.

AFS-14 NC Cooperative Management Program for Albemarle Sound-Roanoke River Striped Bass. Objectives are to summarize the status, estimate the commercial and recreational catch and effort, determine nursery area ecology, and estimate the harvestable population of striped bass in Albemarle Sound-Roanoke River.

AFCS-16 NC North Carolina Anadromous Fish Management Program. Objective is to monitor anadromous fish populations to determine growth, abundance, age, species, size, sex, migration, distribution, and harvest. Additional efforts are directed toward locating spawning and nursery areas and experimentally stocking striped bass.

AFC-17 NC A Study of River Herring Spawning and Water Quality in Chowan River, North Carolina.

AFS-8 SC Monitoring and Assessment of the South Carolina Commercial Fishery for American Shad.

AFC-8 SC Enhancement of Striped Bass Population in Santee River. Objective is to stock striped bass fingerlings in the Santee River and assess their survival.

AFS-9 SC Life History, Ecology, Culture, and Management of the Atlantic Sturgeon, *Acipenser oxyrhynchus oxyrhynchus* (Mitchell), in South Carolina. Objectives are to summarize Atlantic sturgeon catches, describe life history and ecology, and develop methods for propagating Atlantic sturgeon.

AFS-3 SC Pre-Rediversion Studies of the Santee and Cooper Rivers. Objectives are to monitor blueback herring

harvest in Cooper River, count herring movement into Lake Moultrie, and collect fish population and life history data of all anadromous fishes and selected resident fish in the Santee and Cooper Rivers and tributaries.

F-30 GA <u>Coastal Region Fisheries Investigations</u>. Objectives are to describe selected physical, chemical, and environmental features of the Savannah River and its basin and fish community; rear and release striped bass fingerlings in selected reservoirs and coastal streams statewide; and evaluate effects of light on striped bass fingerlings.

AFC-11 GA <u>Georgia Commercial Shad Assessment</u>.

AFC-18 GA <u>Georgia Commercial Shad Assessment</u>.

AFCS-12 AL <u>Striped Bass Production and Stocking Experiments in Alabama Coastal Areas</u>. Objective is to rear and release striped bass fingerlings into the coastal waters of Alabama to reestablish historical populations.

AFC-13 AL Objective is to increase yield of striped bass fingerlings through intensive culturing methods.

AFCS-7 MS <u>Striped Bass Restoration Program</u>. Objectives are to increase, by stocking, the resident population of South Carolina striped bass now in the Biloxi Bay system; establish a source of fry from Mississippi brood fish; and monitor striped bass in coastal streams.

AFS-06 LA <u>Striped Bass Production - River Systems</u>. Objective is to rear and stock striped bass fingerlings in coastal streams.

2.2 Fish and Wildlife Service Research Programs

2.2.1 Cooperative Fishery Research Units

The North Carolina Unit is studying cryogenic preservation of striped bass and shortnose sturgeon sperm and potentials for cage and pond culture of hybrids. The unit in Georgia is examining movements, distribution, and abundance of shortnose sturgeons in the Altamaha River. The Alabama Unit is conducting a survey of striped bass strains in the lower Tallapoosa River to support management activity of an intensive sport fishery.

The Field Research Unit of this laboratory in Athens, Georgia, is conducting research on contaminant residues in adults, eggs, and young-of-the-year striped bass, and evaluating the relationship between reproductive success, larval survival, and contaminant residues in striped bass from southeastern United States waters.

2.2.3 National Fish Health Research Laboratory

The National Fish Health Research Laboratory located in Leetown, West Virginia, is conducting studies on diseases of American shad and striped bass. Projects include: 1) survey of viral erythrocytic necrosis of striped bass and American shad in Pennsylvania; 2) live-cell development and cell culture of American shad; 3) testing new chematherapeutants on bacterial diseases of striped bass; and 4) development of diagnostic and detection procedures for bacterial pathogens of striped bass.

2.2.4 Southeastern Fish Cultural Laboratory

This laboratory is located in Marion, Alabama and is examining various aspects of striped bass culture. Current research projects are: 1) evaluation of growth and survival of adult striped bass in shallow ponds; 2) performance of striped bass in subsurface silos; 3) determination of environmental requirements necessary for maintaining striped bass broodstock; 4) evaluation of advanced fingerlings striped bass production in intensively-managed pond and tank systems; and 5) maximization of survival, growth, and production of striped bass fry in intensively-managed culture systems.

2.2.5 Southeast Reservoir Investigations

This facility, located in Clemson, South Carolina, is a field station of the National Reservoir Research program. Presently this station is studying certain life history parameters of blueback herring and measurings its usefulness as a prey species in three southeastern reservoirs. A study to determine the effects of small-scale hydroelectric development on anadromous fishery resources in Georgia and South Carolina is scheduled to start in FY 1982.

2.3 Anadromous Fish Propagation and Distribution

2.3.1 National Fish Hatchery System

2.3.1.1 Program Goal and Objectives

The goal of the Fish and Wildlife Service is to conserve the Nation's freshwater and anadromous fishery resources for the benefit of the people. Distribution of fish from the Federal hatchery system assists in meeting this goal in accordance with the following objectives:

a) To restore and/or maintain existing freshwater and anadromous fishery resources in suitable streams, rivers, or lakes of the United States.

b) To increase the fisheries by restoring destroyed or depleted fishery resources.

c) To create greater fisheries by upgrading existing fish populations, developing new bodies of water, and introducing new species.

d) To aid States in the management and development of fishery resources.

e) To protect the Nation's fisheries by limiting the introduction or distribution of diseased fish and their attendant pathogens.

f) To control the introduction and population levels of exotic species damaging to the fishery resources or aquatic ecosystem.

g) To carry out responsibilities established by treaties and other commitments of the Federal Government to maintain or restore fishery resources.

It is the policy of the U.S. Fish and Wildlife Service to allocate or distribute the output of its National Fish Hatcheries in the following order of priority:

1) International waters, such as coastal and Great Lakes areas, and waters on land owned, controlled, and managed by Federal agencies or recognized Indian tribes (international treaties or cooperative agreements are usually involved).

2) Waters on land owned by the Federal Government and managed by State agencies (cooperative agreements are usually involved).

3) Waters on State or privately owned land managed by a Federal agency (cooperative agreements usually involved).

4) Waters which border or cross State boundaries.

5) Waters owned and managed by State agencies (cooperative agreements occasionally involved).

6) Privately owned waters.

2.3.1.2 Striped Bass Production and Distribution - Region 4, 1975 through 1980.

Striped bass is the only anadromous species that is produced and distributed to waters contiguous with the South Atlantic Ocean and Gulf of Mexico within Region 4. The striped bass program is in response to the stated objectives of the U.S. Fish and Wildlife Service in cooperation with the involved States. A summary of these production and distribution activities is presented in Table 2.3-1. Activities at the Bears Bluff, South Carolina, substation will contribute to our anadromous program (Section 3.2.13).

No other species of anadromous fish are produced and distributed in this region. However, with the initiation of the sturgeon fish culture development program at the Orangeburg National Fish Hatchery, South Carolina (and the Bears Bluff substation), the Service is hopeful of full-scale production and distribution in the near future (Section 3.3.13.5).

Total expenditures by the U.S. Fish and Wildlife Service for coastal anadromous activities, including administration and fish culture, were $198,200 during fiscal year 1980 in Region 4. These dollars were from Resource Management funding and not Anadromous Grant funding.

2.3.1.3 Anadromous Stocking Requirements

All anadromous fish production conducted in the southeastern United States by the U.S. Fish and Wildlife Service is funded by Resource Management funds and not by Anadromous Grant Program funds. Many of the fish produced support State-Federal Anadromous Grant Program activities. Present and future State stocking requirements met by the National Fish Hatchery system are presented in Table 2.3-2.

Table 2.3-1. Striped bass stocked in coastal waters from National Fish Hatcheries (fingerlings to eight-inch fish), 1975 through 1980.

Year	Source of Fry	State Waters	Production Costs (Dollars)	Number Stocked
1975	MD	FL	9,000	600,000
	MD	NY	2,000	90,000
	NC	NC	6,000	300,000
	NY	GA	-	100,080
	SC	MS	2,000	50,000
	SC	AL	2,000	50,000
	SC	SC	6,000	500,000
1976	SC	FL	3,000	150,000
	VA	NC	5,000	240,000
	SC	MS	6,000	314,000
	SC	AL	4,000	289,000
	SC	SC	3,000	200,000
	LA	LA	4,000	80,000
1977	SC	GA	-	90,000
	GA	FL	9,000	622,000
	NC	NC	4,000	255,000
	SC	MS	7,000	406,000
	FL	AL	4,000	259,000
	SC	SC	9,000	588,000
	LA	LA	14,000	1,635,697
1978	SC	MS	6,000	300,000
	GA	AL	3,000	300,000
	FL	FL	4,000	205,000
	NC	NC	6,000	405,000
	SC	SC	3,000	85,000
	LA	LA	10,000	1,478,000
1979	SC	SC	8,000	397,000
	GA	GA	-	70,400
	SC	MS	6,000	298,000
	FL	FL	14,000	450,000
	NC	NC	8,000	401,000
	LA	LA	16,000	784,000
	NC	AL	6,000	314,000

Table 2.3-1. Striped bass stocking (con't.).

Year	Source of Fry	State Waters	Production Costs (Dollars)	Number Stocked
1980	SC	SC	12,000	296,000
	VA	NC	16,000	585,876
	VA	MS	8,000	168,000
	SC	MS	7,000	205,000
	GA	GA	-	10,025
	FL	MS	11,000	16,687
	SC	AL	6,000	300,000
	FL	FL	14,000	132,000
1981	GA	GA	-	36,898

Table 2.3-2. Proposed production of Atlantic and Gulf race striped bass by the National Fish Hatchery System. All anadromous fish production carried out in the southeastern United States by the Fish and Wildlife Service is funded with Resource Management funding and not with Anadromous Grant Program funding. Many of these fish support State-Federal Anadromous Grant Program activities.

	1982			1985		
State	Number	Size	Estimated Cost [1]	Number	Size	Estimated Cost [2]
North Carolina	110,000	6-8"	$ 13,200	500,000	6-8"	$65,000
	3,500,000	1-2"	210,000	400,000	1-2"	28,000
South Carolina	15,000	6-8"	1,800	15,000	6-8"	1,950
Georgia	80,000	1-2"	4,800	100,000	1-2"	7,000
Florida	12,000	6-8"	1,440	20,000	6-8"	2,600
	150,000	1-2"	9,000	200,000	1-2"	14,000
Alabama	396,000	1-2"	23,760	400,000	1-2"	28,000
Mississippi	850,000	1-2"	51,000	600,000	1-2"	42,000
	15,000	6-8"	1,800	15,000	6-8"	1,950
Louisiana	300,000	1-2"	18,000	700,000	1-2"	49,000
Totals	5,428,000		$344,800	2,950,000		$239,500

[1] Cost: 1982

1-2" @ $0.06 each
6-8" @ $0.12 each

[2] Cost: 1985

1-2" @ $0.07 each
6-8" @ $0.13 each

2.3.2 State Fish Hatchery Systems

2.3.2.1 North Carolina

Information detailing production activities of State hatcheries was not available.

2.3.2.2 South Carolina

Information detailing production activities of State hatcheries was not available.

2.3.2.3 Georgia

The Fisheries Section of the Georgia Department of Natural Resources routinely operates six State hatcheries for warmwater fish production. Bluegill, redear sunfish, largemouth bass, channel catfish, and small numbers of other warmwater species are produced for stocking newly-constructed or renovated private ponds and to meet specific management needs of public waters. Striped bass and striped bass x white bass hybrids, however, are the primary warmwater species produced for public water stockings within the State. Striped bass and hybrid bass fry are artificially propagated at the Richmond Hill Fish Hatchery from broodfish collected during their natural spawning runs in Georgia coastal rivers (primarily the Savannah and Ogeechee Rivers). Fry are reared to fingerlings in all the State fish hatcheries and are supplied to designated Federal hatcheries in Georgia for rearing and stocking in State waters. In addition, fry are occasionally donated to other State agencies primarily for rearing and stocking in adjoining State waters.

The Atlantic striped bass and striped bass x white bass hybrid are the only anadromous species produced and distributed by Georgia in Georgia waters contiguous with the Atlantic Ocean and the Gulf of Mexico. Georgia's on-going striped/hybrid bass production and stocking program was initiated in response to the need and desire to establish inland fisheries for these species in reservoirs and lakes, to utilize abundant forage resources, and to enhance native striped bass populations in the State's coastal river systems. A summary of the production and distribution activities of Georgia's hatchery system since 1975 is presented in Table 2.3-3.

Table 2.3-3. Striped bass and striped bass x white bass hybrid fingerling stocked from Georgia fish hatcheries, 1975 through 1980 (R.M. Gennings 1981, pers. comm.).

Year	Source of Fry	Species or Hybrid	Number Stocked in Georgia Rivers*	Number Stocked in Georgia Inland Reservoirs & Lakes	Combined Statewide Production & Distribution Cost (Dollars)
1975	GA	Striped bass fingerling	------	21,540	Unavailable
	NY	Advanced fingerling striped bass	34,988	------	Unavailable
	GA	Hybrid bass fingerling	------	80,868	Unavailable
1976	GA	Striped bass fingerlings	------	18,125	Unavailable
	GA	Advanced fingerling striped bass	18,228	------	Unavailable
	GA	Hybrid bass fingerling	------	285,318	Unavailable
1977	GA	Striped bass fingerling	------	4,494	Unavailable
	GA	Advanced fingerling striped bass	------	------	Unavailable
	GA	Hybrid bass fingerling	------	1,187,654	Unavailable
1978	GA	Striped bass fingerling	109,690	217,123	18,302
	GA	Hybrid bass fingerling	------	1,107,945	15,511
1979	GA	Striped bass fingerling	312,110	490,297	23,270
	GA	Hybrid bass fingerling	------	1,980,147	21,782
1980	GA	Striped bass fingerling	111,799	434,285	10,376
	GA	Hybrid bass fingerling	------	874,895	23,622

*Includes anadromous rivers of the Atlantic coast and certain streams contiguous with the Gulf of Mexico.

2.3.2.4 Florida

The production of striped bass and *Morone* hybrid by Florida State hatcheries is approximately 12,000,000 fish per year (Table 2.3-4). All fry originate in-state from native stock of Atlantic race striped bass.

2.3.2.5 Alabama

Striped bass and *Morone* hybrid stocking in Alabama waters is summarized in Table 2.3-5.

2.3.2.6 Mississippi

A stocking program for striped bass in Mississippi coastal waters utilizes all fish reared by the Gulf Coast Research Laboratory (GCRL)(Table 2.3-6). None of the coastal waters stocking programs has utilized striped bass produced at State fish hatcheries (J. Herring 1981, pers. comm.). Production costs of striped bass at GCRL have varied from a low of $0.03 each to a high of $1.58 per fingerling. All rearing at GCRL is accomplished in an intensive culture system which contains only 33,000 gallons of water. Production costs include amortization of the cost of the facility over the eight-year period (Table 2.3-6). Operation and maintenance of the facility each year accounts for approximately 78% of the production costs (T.D. McIlwain 1981, pers. comm.).

2.3.2.7 Louisiana

The distribution of fish from Louisiana hatcheries assists in the management of the State fishery resources (Table 2.3-7). This is accomplished by restoring depleted fishery resources and establishing anadromous populations in suitable waters where none existed. The allocation of anadromous fish from Louisiana hatcheries is prioritized; suitable lakes and streams tributary to coastal streams receive first priority and coastal streams are secondary (J.J. Guidry 1981, pers. comm.).

2.3.2.8 Texas

The State of Texas has an active stocking program for striped bass (Table 2.3-8). In 1981, 9.17% of the total number of acres available at State hatcheries were utilized for production of striped bass (C.D. Travis 1981, pers. comm.).

Table 2.3-4. Annual production of Atlantic race striped bass and Morone hybrid from Florida state hatcheries (F.J. Ware 1981, pers. comm.).

Species or Hybrid	Annual Production Fry	Fingerlings (40 mm TL)
Striped bass (Atlantic race)	1,000,000	250,000
Striped bass male x white bass female	1,000,000	500,000
White bass male x striped bass female	10,000,000	3,500,000

Table 2.3-5. Striped bass and Morone hybrid stocking in Alabama, 1975 through 1981 (C.D. Kelly 1981, pers. comm.).

Year	Species	Number Stocked
1975	Striped bass	366,297
	Hybrid	77,006
1976	Striped bass	382,535
	Hybrid	238,409
1977	Striped bass	399,337
	Hybrid	194,718
1978	Striped bass	273,415
	Hybrid	5,920
1979	Striped bass	346,414
	Hybrid	273,372
1980	Striped bass	508,110
	Hybrid	64,120
1981	Striped bass	793,456
	Hybrid	152,710

Table 2.3-6. Striped bass reared at the Gulf Coast Research Laboratory and stocked into Mississippi coastal waters (fingerlings to eight-inch fish), 1974 through 1981 (T.D. McIlwain 1981, pers. comm.).

Year	Source of Fry	Production Costs (Dollars)	Number Stocked
1974	SC	3,600	21,144
	MD	4,100	25,121
	VA	1,500	8,992
	MD*	110	647
	VA*	95	563
1975	SC	10,200	6,424
1976	SC	9,000	179,749
	NY	1,400	27,421
1977	SC	9,800	122,782
	NC	625	7,794
	MS	1,500	18,808
1978	SC	7,000	232,586
	MS	4,400	145,000
1979	SC	8,200	137,159
	NC	1,700	28,154
	MS	3,400	56,666
1980	SC	6,100	204,000
	VA	6,700	222,800
1981	SC	14,600	292,473
	VA	2,200	43,876

*Advanced fingerlings 6-10".

Table 2.3-7. Striped bass production and distribution in coastal waters of Louisiana, 1967 through 1980, (J.J. Guidry 1981, pers. comm.).

Project Number	Source of Fry	Year Class	Calcasieu	Mermentau	Pearl	Tchefuncte	Bayou LaCombe	Biloxi Marsh
AFS-01	SC	1967	-------	---------	-----	8,700	------	750,000*
AFS-04	MD	1972	-------	18	-----	-------	18	15,000
	MD	1973	-------	150,000	54,000	1,600	-------	--------
	VA	1974	27,905	---------	-----	17,200	-------	--------
AFS-06	SC	1975	146,085	---------	74,237	7,182	-------	--------
	SC	1976	304,000	---------	119,425	19,300	36,695	--------
	SC	1977	177,985	---------	55,644	6,552	-------	--------
	SC	1978	209,087	---------	121,325	-------	-------	--------
	SC	1979	96,868	48,973	78,313	14,735	-------	--------
	SC	1980	54,427	112,015	107,654	29,916	5,988	--------
Totals			1,016,357	311,006	610,598	105,185	42,701	765,000

Total coastal stockings - 2,850,847

*Fry

Table 2.3-8. Striped bass stocking in Texas waters from Texas Parks and Wildlife Department hatcheries (1.25" fish), 1968 through 1981 (C.D. Travis 1981, pers. comm.).

Year	Fingerlings	Production Cost (Dollars)
1968	16,830	-
1969	49,334	-
1970	28,900	-
1971	67,512	-
1972	80,703	-
1973	670,446	-
1974	613,668	-
1975	270,846	-
1976	1,318,162	-
1977	4,386,759	241,272
1978	1,121,984	153,712
1979	1,318,200	77,774
1980	683,758	55,384
1981	1,370,521	

2.3.3 Other Management Activities

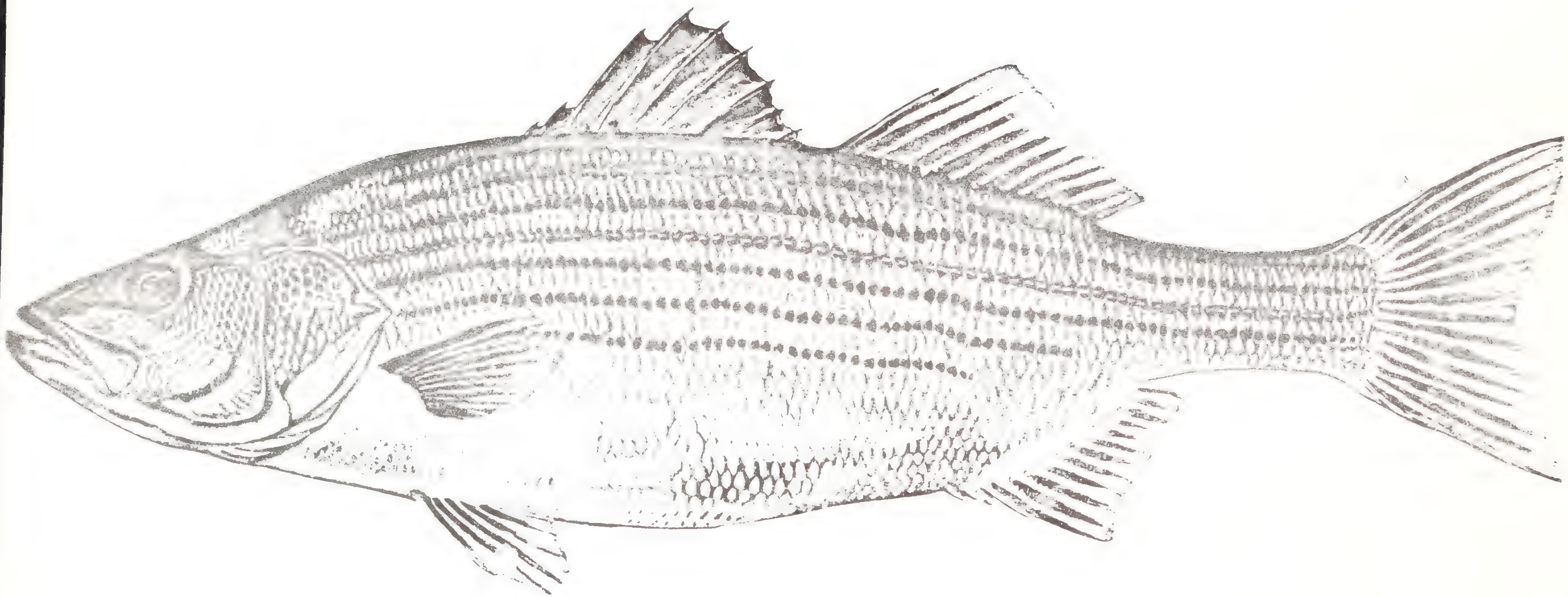
Management activities, both ongoing and proposed, are listed for each species in Section 3 under the subheading "Protection and Management."

2.4 Chafee Amendment

An action plan has been prepared to serve as an overall strategy to study the decline of coastal stocks of striped bass from Maine to North Carolina. This study was authorized by Section 7 of the Anadromous Fish Conservation Act Amendment, Public Law 96-118. Section 7 directs the Secretaries of the Interior and Commerce Departments to conduct studies to monitor the status of the striped bass populations, and to determine the factors responsible for the decline in numbers of striped bass. The Congress (Senate Report 96-174) intended that these studies be coordinated with ongoing programs, such as the State/Federal Fisheries Management Program, but not supplant them. The Emergency Study will focus on enhancing our knowledge about the striped bass resource and factors harmful to it. This new knowledge will aid the States and the Federal Government in developing sound and equitable plans for managing the fishery and protecting critical habitat.

The Plan provides for direct links with those agencies having the management of environmental regulatory authorities and responsibilities to protect the striped bass fishery. The Plan also provides for public involvement by sport and commercial fishermen who have demonstrated a strong vital interest in the future of this most important fishery.

The inclusion of provisions for an emergency striped bass study in Public Law 96-118 was the result of a perceived decline in the coastal striped bass stocks from Maine to North Carolina, which began in 1974 and reached a 21-year low by 1978. Furthermore, there appeared to be an absence of small bass in the coastal migratory stock which suggested that recruitment had declined. This notion was supported by annual young-of-the-year abundance surveys in Maryland waters of Chesapeake Bay. The coastal migratory stock of bass is largely maintained by periodic formation of dominant-year classes. The last such year class, the largest in 30 years, occurred in 1970 and resulted in the peak landings in 1973. The rapid decline in landings since 1973 is largely the result of low levels of recruitment and no subsequent dominant-year classes.



STRIPED BASS (*Morone saxatilis*)

3. DESCRIPTION OF ANADROMOUS RESOURCES

3.1 Striped Bass - Atlantic Race (*Morone saxatilis* (Walbaum))

One of the most important commercial and recreational species on the U.S. Atlantic coast is the striped bass, also commonly known as rockfish, rock, striped, and linesides (Setzler et al. 1980). Adults ascend rivers in the spring to spawn in fresh or brackish waters and remain for a short period before returning to the sea. Populations north of North Carolina typically migrate in a northerly direction during summer and return to wintering areas prior to entering natal streams to spawn the following spring. Northern Atlantic striped bass stocks and their migratory patterns were recently summarized by Hardy (1978), Setzler et al. (1980), and others. An indexed bibliography of striped bass, covering literature from 1670 to 1976, was presented by Horseman and Kernehan (1976).

Striped bass populations from southern North Carolina through Florida do not contribute to the northward migration described above, and most populations along the Southeast Atlantic coast appear to be endemic riverine (McIlwain 1980a). Striped bass in the Gulf of Mexico were identified by Barkaloo (1970) as being a separate race from these along the eastern seaboard. Life history aspects of the Gulf race striped bass, and populations of Atlantic race striped bass stocked in Gulf coast waters, are presented in Section 3.2. The present section (3.1) deals with information pertaining to populations along the Southeast Atlantic coast.

3.1.1 Historical Significance

The striped bass was an important natural resource in North America before the arrival of the first colonists. Setzler et al. (1980) presented the following historial review: "Striped bass were caught and dried in great numbers by the Indians in New England. Striped bass and codfish were the first natural resources in Colonial America that were subject to conservation measures enacted by statute. In 1639, the General Court of the Massachusetts Bay Colony passed a law that neither fish could be sold as fertilizer. But the catch increased, and by 1776 New York and Massachusetts had passed laws prohibiting sales of these fish in winter months (Bayless 1964). An act of the Plymouth Colony in 1670 stated that all income accrued annually to the colony from the fisheries at Cape Cod for striped bass, mackerel, or herring be used for a free school in some town of the jurisdiction. As a result of this act the first public school of the New World was made possible through moneys derived in the part from the sale of striped bass. A portion of this fund was also utilized in aiding the widows and orphans of men formerly engaged in the service of the Colony (Pearson 1938)."

3.1.1.1 North Carolina

Baker (1968) summarized the distribution of striped bass populations in North Carolina waters. Striped bass frequent all sounds, estuaries, and large rivers of North Carolina and are found in the "big water" sections of many smaller streams. Striped bass are not often taken from streams with less than 1,000 ft^2 cross-sectional area. Stream discharges seem to have no significance except during spawning runs. Distribution is limited by two major factors - dams and stream size. The upstream distribution of striped bass in the Roanoke, Tar, Neuse, and Pee Dee rivers is limited by dams. Upstream migration in the Cape Fear River is blocked by three navigation locks. Locking procedures for passage of American shad during their spawning run should increase the incidence of striped bass above the locks and should result in restoring their natural range (Baker 1968).

Striped bass have been commercially and recreationally important since the 1800s. In 1887, 499,586 pounds of striped bass were landed for a value of $24,944; by 1902, landings increased to 1,183,400 pounds valued at $114,111 (Smith 1907). From April 1967 to March 1968 sport fishermen in North Carolina caught over 96,000 anadromous fish, 62% of which were striped bass (Baker 1968). Of this number, 93% came from Roanoke-Chowan-Albemarle Sound population, and only five percent came from the Tar-Pamlico River system (Baker 1968).

Striped bass is the most valuable sport and commercial fish in the Roanoke River and Albemarle Sound (Baker 1968, Hassler and Hill 1981). The spawning population of the Roanoke River maintains a continuing supply of young stripers for both special device fishermen and sport fishermen in inland waters as well as for commercial fishermen in Albemarle Sound (Baker 1968). The mean total catch of commercial striped bass landings from 1887 to 1980 was approximately 790,000 pounds per year, ranging from a low of 246,000 pounds in 1979 to a peak of 2,318,000 pounds in 1970 (Hassler and Hill 1981). The eight highest catches ever recorded were taken from 1967 through 1976 resulting from heavy landings of striped bass on the Outer Banks. These record catches also caused bitter controversies between resident and non-resident fishing crews, and also between commercial and sport fishermen. The National Park Service served as the intermediary in the dispute, which resulted in allowing commercial fishing privileges to bonafide Outer Banks residents only (Hassler and Hill 1981). In 1955, the cooperative Roanoke-Albemarle Striped Bass Studies were originated as part of the Steering Committee for Roanoke River Studies and have been conducted annually to provide long-term information on the status and abundance of striped bass in this area (Hassler and Hill 1981).

Early culture of striped bass in North Carolina was reviewed by Smith (1907). In 1873, under the direction of U.S. Fish Commissioner Baird, 100,000 striped bass were hatched at Weldon (primary spawning area on the Roanoke River) and planted in local waters. From 1879 to 1884, the State Superintendent of Fisheries, Mr. S.G. Worth, performed experimental work on the hatching of Roanoke River striped bass near Weldon. In 1884, with financial aid by the United State Commissioner of Fisheries, over four million eggs were collected. This laid the foundation for striped bass work taken up later by Worth as a superintendent of the Bureau of Fisheries, when temporary hatching stations were established near Weldon on the Roanoke River. The Weldon Hatchery produced and released several million young stripers each season (Smith 1907).

3.1.1.4 Florida

Natural populations of Atlantic race striped bass have been reported in the St. Marys, Nassau, St. Johns, Trout, and Oklawaha Rivers on the Florida Atlantic coast (McLane 1958). A distinct race of striped bass, separate from those on the Atlantic coast, has been reported for Gulf coast river systems, including the Ocklockonee, Chipola, Apalachicola, Yellow, Blackwater, Escambia, and Perdido Rivers (McLane 1958). These populations were probably separated from Atlantic coast populations after the closing of the Suwannee Straits in the late Pleistocene (McLane 1958). Stocking programs have introduced populations of Atlantic race striped bass in Gulf race river systems. Striped bass populations along the Florida Gulf coast are considered in Section 3.2.

A small commercial fishery was presented in northeast Florida from the late 1800s until recently. Commercial landings from northeast Florida appeared in commercial statistics only twice; 100 pounds were landed in 1939 and less than 500 pounds were reported in 1960 (McIlwain 1980a). The primary river system is the St. Johns River, although local reports have indicated good seasonal catches from the St. Marys and Nassau Rivers (Barkaloo (1967). Striped bass are now legally protected from the commercial fishery (Chapter 370.112 of the Florida Statutes), with the primary objective of increasing population levels (Williams and Grey 1975). Culture and management of this fish have been undertaken by the Florida Game and Fresh Water Fish Commission to increase stocks for the sport fishery and to control the large numbers of gizzard shad, *Dorosoma cepedianum*, and threadfin shad, *Dorosoma petenense*, in freshwater lakes and rivers (Williams and Grey 1975).

Striped bass in the St. Johns River is very likely restricted to freshwater and constitutes a nonmigratory local race low in population density (McLane 1955). Meristic characters indicate the population is 75% separable from populations to the north (E.C. Raney in McLane 1955).

3.1.2 Distribution

3.1.2.1 Range

Atlantic race striped bass range from the St. Lawrence River, Canada, to the St. Johns River, Florida (McLane 1955). Small spawning populations exist in the St. Marys and Nassau Rivers, with stragglers occurring as far south as Pellicer Creek and Tomoka River, Florida (Williams and Grey 1975). In recent years, Atlantic race striped bass have been stocked in river systems throughout the Gulf of Mexico from West Florida to Texas. Populations were also introduced on the Pacific coast in the late 1800s and presently range from Baja, California to the Columbia River, Washington (Tagatz 1961).

3.1.2.2 Eggs

Hardy (1978) summarized information relevant to egg distribution. Striped bass eggs are deposited near the surface. Slightly heavier than freshwater, they are easily floated by agitation. Immediately after fertilization the eggs become less buoyant, requiring vertical water movement of 125 cm s^{-1} for suspension. Within two to three hours they regain buoyancy, requiring only 60 cm s^{-1} for suspension. Striped bass eggs drift with the current, sometimes at speeds up to 2.06 km h^{-1}. Eggs have been collected in currents ranging from 54.4 to 269.6 m^3s^{-1}, although generally they are most abundant near the bottom in currents less than 30 cm s^{-1}. Viable eggs have been collected in brackish water up to 11.3^{o}/oo (Hardy 1978).

3.1.2.3 Larvae

Larval distribution was summarized by Hardy (1978). At one to two days larvae are near the surface, sometimes attached to floating objects. At four to five days, larvae begin to form schools. Two weeks after hatching, larvae forage on the bottom, sometimes settling over silt and mud. Larvae are found in both fresh and brackish waters, and schools remain in the shore zone throughout the first summer. Larger larvae move downstream as summer progresses and by autumn some individuals reach the mouths of estuaries (Hardy 1978).

3.1.2.4 Juveniles

Juvenile patterns of distribution were reviewed by Hardy (1978). Juvenile striped bass remain in schools into the second year of life and are found in streams, rivers, bays, sounds, sheltered coves, flats, and freshwater ponds. Young-of-the-year are usually more abundant in shallow areas with pronounced currents and clean bottoms

of sand or gravel, and rarely occur over soft bottoms. Juveniles exhibit a general downstream movement, which may be more pronounced during their second summer of life at 150 mm or larger (Hardy 1978).

3.1.2.5 Adults

Adult striped bass populations apparently are endemic and riverine south of the Virginia-North Carolina border. Little is known about adult distribution and local habitats along the South Atlantic coast. The general distribution of adult stripers was summarized by Hardy (1978). Striped bass typically school and are found inshore in some current over bottoms of rock, boulders, gravel, sand, muck and detritus, grass, moss, and mussel beds. Adults in estuarine and marine environments occur along sandy beaches, rocky shores, shallow bays, troughs and gullies, sand bars, in surf, and sometimes under rafts of floating rockweed. Stripers usually remain within 6.4 to 8.0 km of shore and may range beyond 16 km; occasional strays have been recorded offshore as far as 97 to 113 km. Adults generally overwinter in bays, estuaries, delta regions, rivers, and sometimes the open sea at depths up to 37 m and at minimum salinity of less than 10 $^{o}/oo$. Spawning migrations begin as early as February or March and continue into July, depending on latitude (Hardy 1978).

3.1.3. Reproduction

3.1.3.1 Maturity

The rate at which striped bass reach sexual maturity increases with warmer mean temperatures (Setzler et al. 1980). Males reach sexual maturity at an earlier age than females. Minimum lengths at maturity are approximately 174 mm TL for males (Raney 1952) and 432 mm TL for females (Clark 1968). Males mature primarily at age II (Tagatz 1961) although males in Florida may show "slight milt discharge" by 11 months (Ware 1971). The average percentage of the female population which matures by age III is 18.2%, age IV 25 to 94%, age V 75 to 100%, age VI 95 to 98%, and 100% after age VI (Hardy 1978).

3.1.3.2 Mating

Mating is polygamous; while spawning a female may be surrounded by as many as 50 males (Merrimen 1941). Spawning occurs at or near the surface and eggs are broadcast at random into the water (Raney 1952).

3.1.3.3 Fertilization

Eggs are released in open water of rivers where they are fertilized.

3.1.3.4 Fecundity

Wide differences in fecundity estimates may be due to the various stages of egg maturity - both ripe and immature - that have been used in estimating fecundity; published averages are approximately 700,000 eggs per female (Hardy 1978). Fecundity estimates range from 15,000 eggs in a 46 cm fish (Mansueti and Hollis 1963) to 40,507,500 (all stages of maturity) in an age XIII, 14.5 kg fish (Jackson and Tiller 1952). Eggs for three consecutive seasons may be contained in the ovary simultaneously (DeArmon 1948).

Albemarle Sound striped bass are quite prolific; each mature female produces about 80,000 eggs per pound of body weight each spawning season (Street 1975). Roanoke River females less than 27.2 kg produce between 138,000 and 497,000 ova, or 105,600 to 215,600 ova per kg of body weight (Lewis and Bonner 1966). Fecundity of stripers ages VII through XIII in waters offshore North Carolina range from 614,243 to 4,057,059 eggs per female, with a mean of 2,462,372. The relationship of fecundity to fish length, weight, and age for offshore North Carolina stocks are:

FECUNDITY - FORK LENGTH (cm)

$$F = 9.33\times10^{4}FL - 6.24\times10^{6}, \quad r = 0.85$$

FECUNDITY - WEIGHT (kg)

$$F = 2.18\times10^{5}W - 1.17\times10^{4}, \quad r = 0.86$$

FECUNDITY - AGE (years)

$$F = 4.33\times10^{5}A - 1.78\times10^{6}, \quad r = 0.66$$

(Holland and Yelverton 1973).

3.1.4 Spawning

3.1.4.1 Season and Location

The onset of striped bass spawning occurs later in the season with increasing latitude (Table 3.1-1). Spawning begins during February in Florida and continues through June or July along the southern shore of the Gulf of St. Lawrence and the lower St. Lawrence River. The location of major spawning grounds within an individual river (Table 3.1-2) may change from year to year (Neal 1964, Humphries 1966). Duration of spawning activity, based on presence of eggs in the system, ranges from eight (Hollis 1967) to 44 days (May and Fuller 1965).

3.1.4.2 Temperature

Striped bass spawning occurs between 10.0 (Nichols 1966a) and 25.0 C (Merriman 1941). Spawning activity in river systems within Region 4 generally begins at 13.0 C or higher and ends at temperatures below 16.7 to 21.7 C. Sudden drops in temperature and the passage of storm fronts result in cessation of spawning activity (Calhoun et al. 1950). Spawning temperatures in specific river systems are:

ROANOKE RIVER - 13 to 21.7 C; peak 16.7 to 19.4 C (Shannon and Smith 1968, Shannon 1970, Street 1975). 90% occurs from 15.4 C to 20.3 C (Hassler and Hill 1981).

ALBEMARLE SOUND TRIBUTARIES - peak 18 to 19 C (Trent 1962).

NEUSE RIVER - 13.5 to 24 C; peak 20 to 21.5 C (Hawkins 1979).

CAPE FEAR RIVER - peak 18 to 19 C (Sholar 1977b, Fischer 1980).

NORTHEAST CAPE FEAR RIVER - 14 to 22 C; peak 19 C (Sholar 1977b).

WACCAMAW - PEE DEE SYSTEM - Surface temperatures between 15.6 and 21.1 C (1974 to 1976) (Crochet et al. 1976).

CONGAREE RIVER - lowest 15.5 C (May and Fuller 1965).

SANTEE COOPER RESERVOIR - lowest 14.4 C; peak 21.7 C (Scruggs 1957).

OGEECHEE AND SAVANNAH RIVERS - 16.5-17.8 to 22.2-23.4 C (Smith 1973).

ST. JOHNS RIVER - approximately 13 to 24 C (data from Barkaloo 1970).

Table 3.1-1. Spawning season of striped bass (Atlantic race).

RIVER SYSTEM	SEASON	SOURCE(S)
Delaware River	Late May to mid-July Peak: June	Raney (1952)
Roanoke River	April 15 to June 5 Peak: May 10-20	W.W. Hassler (1981, pers. comm.)
Neuse River	Late March to late May April to mid-May	Hawkins (1979) Baker (1968)
Northeast Cape Fear River	April to early May	Sholar (1977b)
Cape Fear River	Mid-April to mid-May	Fischer (1980)
Waccamaw-Pee Dee system	Peak: April	Crochet et. al. (1976)
Congaree River	April 23 to June 5	May and Fuller (1965)
Wateree River	April 23 to June 5	May and Fuller (1965)
St. Johns River	Mid-February to April 1	Barkaloo (1970)
St. Marys River	March 15 to April 5	F.J. Ware (1981, pers. comm.)
Nassau River	March 15 to April 5	F.J. Ware (1981, pers. comm.)

Table 3.1-2. Spawning grounds of striped bass (Atlantic race).

RIVER SYSTEM	LOCATION	SOURCE(S)
Roanoke River	RM 78 to RM 140, centered at Weldon (RM 130) at Fall Line	W.W. Hassler (1981, pers. comm.)
Tar-Pamlico system	55.6 to 148.2 km upstream from river mouth; 75% within a 37 km area	Humphries (1966)
Neuse River	Middle Neuse from NC Hwy 55 bridge near Kinston (RM 80) to SR 1224 bridge above Goldsboro (RM 145). Major area: NC Hwy 55 bridge to SR 1915 bridge near Goldsboro	Hawkins (1979)
Northeast Cape Fear River	Croom's Bridge to Ness Creek Major area: downstream from Lane's Ferry	Sholar (1977b)
Waccamaw-Pee Dee system	Major area probably in Pee Dee River or Intracoastal Waterway	Crochet et al. (1976)
Congaree River	RM 5 to RM 53. Major area: RM 37	May and Fuller (1965)
Wateree River	Upstream to RM 70; 92% at or downstream from RM 32	May and Fuller (1965)
Savannah River	Little Back River upstream from US HWY 17 bridge to the mouth of Union Creek (30 to 40 km upstream from the river mouth)	McBay (1968), Smith (1970)
St. Johns River system	Perhaps Black Creek Possible sites: Oklawaha and Wekiva Rivers, Dunn's Creek	McLane (1955) Barkaloo (1970)
Pee Dee River	Upstream from US Hwy 301 bridge	White and Curtis (1969)
Black River	Immediately upstream from U.S. Hwy 701 bridge	White and Curtis (1969)

Table 3.1-2. Spawning grounds (cont'd.).

RIVER SYSTEM	LOCATION	SOURCE(S)
Lynches River	Upstream from Hwy 41 bridge	White and Curtis (1969)
Cooper River	Vicinity of the lower end of Tail Race Canal	Cadieu and Bayless (1968)
Ashley River	Near Slands Bridge (US Hwy 17-A bridge, RM 34)	Curtis (1970a), cited in Ulrich et al. (1979)
Combahee River	Somewhere between U.S. Hwy 17 and 17-A bridges	Curtis (1970b), cited in Ulrich et al. (1979)
Altamaha River	At U.S. Hwy 17 bridge (RM 10)	Smith (1970)
Ogeechee River	Between Whitehall and Ford Island (18.4 to 21.0 miles above Ossabow Sound)	McBay (1970)
St. Marys River	Near the junction of Little St. Marys River	F.J. Ware (1981, pers. comm.)
Nassau River	Upstream from I-95 bridge to River Forks	F.J. Ware (1981, pers. comm.)

3.1.4.3 Spawning Habitat

The following information was summarized from Hardy (1978): Striped bass spawning occurs in fresh, turbid water in shallow river areas 0.3 to 6.1 m deep, streams, and creeks. Spawning probably never occurs in lakes, freshwater reservoirs, or in the ocean. Some populations spawn in upper tidal reaches of river systems or in areas just above tidal influence. Other populations run upstream as far as 320 km above saltwater to spawn in turbulent, muddy, silt-laden riffle areas. Such areas are frequently associated with the Fall Line and are characterized by rapids, boulders, and strong currents.

3.1.4.4 Diel Spawning Patterns

Spawning activity as related to light regime varies greatly among river systems. Time of peak spawning activity is highly variable, with sharp spawning peaks of relatively brief duration (Fish and McCoy 1969).

3.1.5. Life History - Eggs and Larvae

3.1.5.1 Hatching and Growth

The incubation period for fertilized striped bass eggs ranges from 29 hours at 23.9 C to 80 hours at 12.2 C (Hardy 1978). The relationship between ambient water temperature and incubation time is expressed by the equation

$$I = -4.60T + 131.6,$$

where I is the development time to hatching in hours and T is temperature in degrees C (Polgar et al. 1976). Eggs will hatch without any period of suspension in the water column, although hatching success increases with increased periods of suspension during the first 15 hours of incubation (Bayless 1968). Percent hatching success is also correlated with substrate composition: coarse sand, 35.7%; plastic, 36.4%; silt, 13.1%; silty-clay, 3.2% and muck detritus, 0.0% (Bayless 1968). Sunlight apparently enhances egg survival (Albrecht 1964, Doroshev 1970).

GROWTH - Length of yolk sac larvae at hatching generally ranges from 2.0 to 3.7 mm TL with a mean length of 3.1 mm (Doroshev 1970). Mean length of larvae one day after hatching is significantly related to temperature; within limits of 12 to 26 C the relationship is

$$L = -0.013T^2 + 0.62T - 2.22, \quad r^2 = 0.70$$

(Morgan et al. 1981). Absorption of the yolk-sac is dependent on water temperature; absorption time is three

days at 23.9 C but up to 22 days may be required to remove all traces of oil (Doroshev 1970). Temperatures between 18 and 21 C are optimal for larval growth between hatching and yolk absorption; larvae had greater dry weights, excluding the oil globule, at yolk-sac absorption than those reared at 15 and 24 C (Rogers et al. 1977). Average duration of the yolk-sac stage is 7 to 14 days (Hardy 1978). Postlarval stages are reached at approximately 240 hours (9 mm) as long as food is available, and by three to four weeks postlarvae become juveniles at about 36 mm TL (Pearson 1938).

FEEDING - Active feeding may begin in four to 10 days after hatching (see review by Hardy 1978) though the mouth may not be functional for as many as 10 days after hatching (Logan 1968). Experiments by Phillips (1967) demonstrated that a majority of fry fed on artificial diets when seven days old, but apparently were unable to digest artificial diets until they had fed on zooplankton. In addition, fry would not accept artificial diets until they had fed on zooplankton. Food preferences, prey size, prey concentration, and feeding strategy of young striped bass were reported by Doroshev (1970). Larvae feed only on mobile planktonic organisms, aiming and rushing at comparatively large prey. Sufficient concentrations of suitable prey organisms are required during the first several days of larval feeding to insure larval year class success (Doroshev 1970). Miller (1977) estimated that first-feeding larvae (5.7 to 6.3 mm TL) search 0.185 to 0.250 liters of water per hour with a strike efficiency between 2.0 and 2.6%. At 22 to 35 mm TL (40 to 50 days after hatching) larvae readily feed on plankton and epibenthos including mysids and chironomid larvae (Doroshev 1970).

METABOLISM - Nitrogen, rather than energy, is the first commodity to be depleted when larvae are starved. Since the offspring of larger striped bass females are larger than the offspring of smaller females, the former may withstand food deprivation longer than the latter (Rogers and Westin 1981).

3.1.5.2 Hardiness

SALINITY - The salinity tolerance of striped bass eggs ranges from 0 to $10^{o}/oo$; larvae up to 20 mm can tolerate salinities ranging from 0 to 15 $^{o}/oo$. A review of salinity tolerances is presented by Setzler et al. (1980). Lal et al. (1977) rapidly acclimated five-day-old larvae that were hatched in freshwater to 20, 40, and 60% seawater and reared them for 33 days. The earliest time striped bass larvae survived transfer to full seawater (33.73 $^{o}/oo$) was 28 days (metamorphosis occurs between 28 and 35 days).

Larval survival was best when acclimated to 10 $^{o}/oo$ seawater just after hatch. Diluted seawater was better for larval survival than freshwater. Optimal growth at one to nine days after hatch occurred in 6.75 $^{o}/oo$ water. With increasing age, optimal growth was positively correlated with increasing salinity; at day 36 (metamorphosis) optimal growth occurred in seawater (Lal et al. 1977).

TEMPERATURE - Striped bass eggs will successfully hatch at temperatures ranging from 14 to 23 C, with optimum hatch occuring from 17 to 20 C (Mansueti 1958). Temperatures of 23.4 C and above decreased hatching percentage and increased deformities in larvae, resulting in 100% larval mortality within 70 hours (Shannon and Smith 1968). Hatching success of fertilized striped bass eggs subjected to simulated power plant effects (time-excess temperatures of 6 to 10 C for 2.5 to 60 minute periods) was reduced only two to eight percent over control eggs, with no apparent effects on behavior or morphology (Schubel and Auld 1973, Schubel 1974). Koo and Johnston (1978) reported deformed larvae developed from eggs exposed to elevated temperatures simulating entrainment in a power plant cooling system. Deformities included shortened bodies, enlarged finfolds, and curved or twisted spines. Severity and incidence of deformities were related to the elevated temperature and exposure time. The lack of normal swimming ability suggested poor eventual survivability (Koo and Johnston 1978). Thermal pollution effects on striped bass were reviewed by Setzler et al. (1980).

SALINITY - TEMPERATURE INTERACTION - Morgan et al. (1981) determined that the interaction of temperature and salinity was a major factor influencing hatch of striped bass, with temperature being most important. The percent hatch (%H) of striped bass eggs at a given temperature (T, C) and salinity (S, $^{o}/oo$) was best expressed by the equation

$$\%H = -0.83T + 30.64T - 0.12(SxT) + 2.22S - 205.80, \quad r^2 = 0.86.$$

From this equation, calculated optimal hatch was 18.2 C and optimal salinity was over 23 $^{o}/oo$, perhaps an artifact. Survival of larvae 24 hours after hatch was related to temperature, salinity, and their interaction. Percent survival (% SUR) was best expressed as

$$\%SUR = -1.03T^2 + 35.86T + 0.54S - 246.63, \quad r^2 = 0.85.$$

Optimum calculated values for larval survival were 18 C and 10 $^{o}/oo$ (Morgan et al. 1981). A study by Otwell and

Merriner (1975) demonstrated great larval hardiness at various salinity-temperature combinations. Mean mortality rates were greater than 50% at 12 C, 3.5% at 18 C, and 7.2% at 24 C. Effects of salinity on mean mortality rates were 23.6% at 20 $^{o}/oo$, 15.4% at 12 $^{o}/oo$, and 11.8% at 4 $^{o}/oo$. The combined effect of temperature x salinity did not produce mortalities exceeding that of either variable alone, indicating no interaction and a high degree of additivity with temperature as the dominant factor. Mortalities at all test salinities - 4, 12, and 20 $^{o}/oo$ - and at 12 C increased with fish age (Otwell and Merriner 1975).

ACCLIMATION - Davies (1970) found larvae able to acclimate to temperature changes much faster than juveniles although the range for survival was much less - 10 to 25 C. Larval acclimation to lower temperatures required 30 to 35 hours, and higher temperatures required only four hours.

OXYGEN - Striped bass eggs were collected in the Neuse River at dissolved oxygen levels of five to 10 ppt (Hawkins 1979).

SUSPENDED SEDIMENTS - Survival of yolk-sac larvae exposed to suspended sediment concentrations of 500 and 1,000 mg l^{-1} for 48 to 96 hours was significantly reduced (Auld and Schubel 1978). Larvae exposed to suspended natural sediments (from Chesapeake and Delaware Canal) for 24 to 48 hour periods exhibited LC_{50} values of 4.85 g l^{-1} and 2.80 g l^{-1}, respectively; striped bass were therefore classifed as a "sensitive species" to suspended sediments (Morgan et al. 1973, cited in Sherk et al. 1975).

pH - Water hardened eggs will hatch throughout the pH range above 5.5 and below 10.0 (Shannon 1967). Neuse River eggs were collected at pH values ranging from 6.4 to 6.9 (Hawkins 1979). Fry survival is best within the pH range 6.5 to 9.5 (Shannon 1967). The 24-hour median tolerance limit (TL_m) for fry averaging 25 mm TL was pH 5.3, and all died in 14.5 hours in pool water adjusted to pH 5.1 (Tatum et al. 1965).

OZONATED WATER - Ozone produced oxidant (OPO) or ozonated water is more toxic to striped bass eggs and prolarvae in freshwater than in estuarine water. Eggs are more resistant than prolarvae in either habitat. Delay in egg hatch occurs in concentrations of 0.05 and 0.10 mg l^{-1} OPO estuarine water. The survival of delayed-hatch striped bass, however, is greater than those hatched under normal conditions (Richardson et al. 1978).

TRANSPORT - Larvae have been transported successfully in concentrations of 9,000 to 13,000 larvae l^{-1} in plastic bags with an oxygen atmosphere (Bayless 1972).

3.1.5.3 Swimming Ability

Swimming efforts of striped bass during early life stages were summarized by Setzler et al. (1980). Yolk-sac larvae attempt to swim to the surface but sink between swimming efforts. Newly-hatched larvae require sufficient turbulence to keep them from settling to the bottom and smothering. Larvae held in aquaria may orient vertically and remain suspended with the head near the water surface. At one or two days old larvae remain near the surface and occasionally attach to floating objects. At two days larvae lay on the bottom or float and at three days swim continuously. After four to five days, larvae reared in aquaria swim horizontally and come to the surface to feed. Reports of vertical distribution of yolk-sac larvae (or prolarvae) in nature vary among river systems; some vertical migration appears to occur for some larvae greater than 14 mm TL (see review by Setzler et al. 1980).

The susceptibility of early life stages of striped bass to industrial water intakes has been investigated extensively. Skinner's (1974) study showed the majority (90%) of larval striped bass 12 to 15 mm capable of avoiding impingement on test screens for six minutes or less in six cm s^{-1} currents. Kerr (1953) reported 80% of striped bass 19 to 38 mm long avoided impingement for 10 minutes in a test flume against a 30.5 cm s^{-1} current, while only five percent avoided impingement in a 43 cm s^{-1} current. Increased water velocities, up to 27 cm s^{-1}, reduced the swimming range of 10, 20, and 50 mm TL striped bass, with magnitude of area covered directly proportional to fish size (Bowles 1976).

3.1.5.4 Chemical Tolerances

The 24-, 48-, and 96-hour acute toxicity levels of ions of copper, zinc, nickel, cadmium, mercury, and chromium to striped bass were determined by Rehwoldt et al. (1971). Literature reporting chemical tolerances of striped bass eggs and larvae was reviewed by Setzler et al. (1980).

COPPER - Yolk-sac larvae are more sensitive than eggs; hatching was retarded at test concentrations of 0.01 to 5.0 mg l^{-1} (O'Rear 1973). A concentration of 0.3 ppm copper sulfate did not appear harmful to striped bass larvae six to 22 days old (Phillips 1967).

ZINC - Yolk-sac larvae are more sensitive than eggs. Zinc concentrations of 0.07 ppm may have caused mortalities in hatching experiments (Tatum et al. 1965).

CHLORINE - At 2.8 ^{o}/oo, the LC_{50} concentration of total residual chlorine (TRC) for striped bass eggs less than 13 hours old was approximately 0.22 ppm; 100% mortality occurred when eggs were subjected to 0.43 ppm TRC. For eggs 24 to 40 hours old, the LC_{50} concentration was approximately 0.27 ppm; 100% mortality occurred at 0.50 ppm TRC. All yolk-sac larvae less than 24 hours old died after exposure to 0.55 ppm TRC; larvae greater than 70 hours old were more sensitive to TRC and all died at a concentration of 0.40 ppm. LC_{50} concentrations for both ages of larvae were approximately 0.20 ppm TRC (Morgan and Prince 1977). At 1 to 3 ^{o}/oo, the estimated incipient LC_{50} concentrations were 0.04 ppm for two-day-old larvae and 0.07 ppm for 12-day-old larvae (Middaugh et al. 1977).

3.1.5.5. Pressure

The following LC_{50} values (dynes cm^{-2}) for time shear exposure experiments on striped bass eggs and larvae were estimated by Ulanowicz (1975):

Exposure	LC_{50} (dynes cm^{-2})	
	Eggs	Larvae
1 minute	450	540
2 minutes	290	435
4 minutes	170	310
2 days	70	

Beck et al. (1975) reported the following results:

Life stage	Exposure	Time	Decreased survival (%)
4-hour eggs	5.7 psia	15 s	9.6%
106-hour larvae	5.6 psia	5 s	20% immediately, 32% after 24 hours
7.5-day-old larvae	6.1 psia	3 s	20-22% after 24 to 72 hours
13- to 17-day-old larvae	45 psia	3 days	36-64% reduction immediately, 38-58% after 24 hours

3.1.6 Life History - Juveniles

3.1.6.1 Nutrition and Growth

FEEDING - Food and feeding habits of juvenile striped bass were reviewed by Setzler et al. (1980). Juveniles 25 to 100 mm are flexible, non-selective feeders which consume mostly insect larvae, polychaetes, larval fish, mysids, and amphipods (Boynton et al. 1981). Prey items depend on fish size, natal river system, and the area utilized as nursery habitat (Table 3.1-3) (Setzler et al. 1980); nearshore habitats are preferred (Boynton et al. 1981). Changes in the estuarine community due to prevailing salinity are reflected in diet composition (Setzler et al. 1980, Boynton et al. 1981). Striped bass will consume any food at age 50 to 60 days; by 80 to 90 days, juveniles 50 to 80 mm TL prefer mysids, gammarids, and fish up to 20 mm long (Doroshev 1970). Visual cues are important during foraging; juveniles reduced interfish distances during feeding and foraged repeatedly in the same location until no food was available (Bowles 1976).

GROWTH - Survival and growth rates of striped bass fry cultured in water of 5 to 10 $^{o}/oo$ salinity were not significantly different (Braid 1977). Laboratory studies by Koo and Ritchie (1973) determined that juvenile growth in the fall, winter, and spring comprised only 29% of the total yearly gain. No growth or feeding occurred below 10 C, and maximum growth occurred at 20 C. Growth is greatest at warm temperatures (24 C) and intermediate salinities (12 $^{o}/oo$) (Otwell and Merriner 1975). Daily growth rates in the Hudson River averaged 0.46 mm day^{-1} but were extended over a short season; mean fall length was 100 mm TL (Rathjen and Miller 1957). Potomac River juveniles grew at rates similar to Hudson River juveniles (Boynton et al. 1977). Trent (1962) reported that growth of young-of-the-year striped bass in Albemarle Sound was roughly linear between June and October, averaging 0.35 mm day^{-1}. Total length after the first season was about 100 mm. Growth rate was not density dependent. The length-weight relationship was expressed as

$$Y = 1.84615 + 2.91977X,$$

where Y is $\log_{10}$ weight in mg and X is $\log_{10}$ total length in cm (Trent 1962). Juveniles present in the Tar-Pamlico System in 1978 ranged from 35 to 165 mm; 88% were caught in July ranging from 35 to 65 mm, four in August (75 to 85 mm), and one in November (165 mm) (Hawkins 1979). Growth rates of juveniles in Albemarle Sound ranged from 0.272 mm day^{-1} in 1955 to 0.664 mm day^{-1} in 1977; mean total lengths on 22 June ranged from 31.56 mm in 1972 to 45.35 mm in 1971 (Hassler and Hill 1981). Significant differences exist

Table 3.1-3. Prey items selected by striped bass (Atlantic race).

RIVER SYSTEM	STRIPER SIZE	ITEM	SOURCE(S)
York River	less than 70 mm TL	Mysids in areas greater than 10‰	Markle and Grant (1970)
	70 to 150 mm TL	Piscivorous (yolk-sac stage Gobiosoma bosci)	
James River	less than 70 mm TL	Insects in areas less than 5‰	Markle and Grant (1970)
	70 to 150 mm TL	Grass shrimp, Palaemonetes sp.	
Delaware River Estuary	50 to 100 mm FL	Summer: River - Neomysis americana, Crangon septemspinosa. Tidal creeks - Palaemonetes pugio, amphipod Corophina, fish and decapods. Fall: fish (Anchoa mitchilli, Menidia menidia)	Bason (1971)
	subadults (1 to 3 yr.)	Primarily feed on bottom: amphipods in summer, mysids in fall; bay anchovy and weakfish Cynoscion regalis	
Offshore North Carolina	280 to 820 mm FL	Menidia menidia Crangon septimspinosa	Sterling and Godwin (1970)
	424 to 1111 mm FL	Cynoscion regalis Cynoscion nebulosus Leiostomus xanthurus Bairdiella chrysura Brevoortia tyrannus Scomber sp. Anchoa hepsetus Etrumerus teres Strongylura sp. Syngnathus sp. Ammodytes americanus Peprilus triacanthus Hepatus epheliticus Portunis sp. Callinectes sapidus Aegathoa oculata Loligo sp.	Holland and Yelverton (1973)

between yearly growth rates of young-of-the-year striped bass in Albermarle Sound from 1955 to 1978, but factors causing these differences are not known. Yearly densities and yearly growth rates of young-of-the-year in the Sound were not significantly correlated. However, a significant positive correlation was found between the mean river discharge for May through July and the estimated growth rate of young in Albemarle Sound. Hassler and Hill suggested that high river flows during May through July carry increased nutrients into Albemarle Sound, which ultimately results in increased growth rates for young-of-the-year striped bass.

In 11 weeks, juveniles residing in the Altamaha River increased fork length from 35 to 88 mm and mean weight from 0.57 to 9.06 gm (Smith 1968). Growth of stripers in Florida is more rapid in cooler months; accelerated growth is apparent in young-of-the-year fish after they attain a size (150 mm) sufficient to utilize shad as a food source (Ware 1971). Striped bass populations can be sufficiently large to depress growth rates; Patuxent River juveniles, age II, showed no increase in size from July to November 1960 (Shearer et al. 1962). However, compensatory growth reduces size variation within age classes with increasing age. Tiller (1943) found smaller yearlings had faster growth rates during their second year. Nicholson (1964) found evidence of compensatory growth in Albemarle Sound fish, occurring most frequently at age II and occasionally in year class III.

METABOLISM - Highest growth rates and best food conversion efficiency occurred at 16 C for juveniles 5 to 10 cm long (Redpath 1972). Maintenance requirements were 3.37, 21.0, 7.5, and 11.5 mg of sludge worms (Tubificidae) per gram fish per day at 8, 12, and 16 and 20 C, respectively (Redpath 1972). The effect of temperature and fish size on the metabolic rate of juveniles was also determined by Klyashtorin and Yarzhombek (1975). Fish weighing one to three grams and acclimated to 22 C varied in Q_{10} values from 2.1 to 1.8 between 15 and 30 C; oxygen consumption ranged from 250 to 1,000 mg kg^{-1} h^{-1}. Oxygen consumption (per unit weight) decreased with increased fish size, as shown by the expression

$$Q/W = 0.36W^{-0.25},$$

where Q is oxygen consumption and W represents the fish weight in grams. Larger fish (8 to 20 g) had metabolic rates of 0.15 g O_2 kg^{-1} h^{-1} at 10 C and 0.45 kg O_2 kg^{-1} h^{-1} at 26 C. The following standard metabolic rates for 22.5 to 68.4 g, 13.0 to 17.5 cm striped bass were determined by Kruger and Brocksen (1978):

°C	Standard metabolic rate mg O_2 kg^{-1} h^{-1}
8	44
12	71
16	151
20	169
24	218

The scope for activity (difference between standard metabolic rate and active metabolic rate at 10 cm s^{-1}) was also determined for the same fish:

°C	Scope for Activity (mg O_2 kg^{-1} h^{-1})	Metabolic cost of swimming at 10 cm s^{-1} (% of standard met. rate)
8	55	130
12	44	66
16	45	29
20	99	59
24	143	63

The optimal temperature for swimming, metabolism, and scope for activity is approximately 16 C for juvenile striped bass (Kruger and Brocksen 1978).

3.1.6.2 Hardiness

SALINITY - Young-of-the-year and yearling striped bass can be transferred directly from freshwater to saltwater, but a reciprocal transfer causes a shock reaction (Loeber 1951, cited in Setzler et al. 1980). Optimal growth and survival occurs in salinities near seawater (Lal et al. 1977).

TEMPERATURE - Temperature avoidance and acclimation studies were summarized by Setzler et al. (1980). Some striped bass survived and fed in water temperatures of 34.4 to 35 C in laboratory tests (Dorfman and Westman 1970). Loeber (1951, cited in Setzler et al. 1980) reported that the upper lethal limit for juveniles was approximately 35 C. Striped bass juveniles may be unable to discern lethal temperatures; none avoided heated waters that proved fatal to some fish (Dorfman 1974). Meldrim and Gift (1971) reported seasonal differences in the response of juveniles to given temperatures; there is a direct relationship between ambient acclimation temperature and the upper

avoidance temperature. Fish acclimated to 27 C water in late August avoided 34 C water, and juveniles acclimated to 5 C water in December avoided 13 C water (Meldrim and Gift 1971). No mortality occurred when juveniles were transferred from cooler to warmer water, but mortality did occur when fish were transferred from 12.8 or 21.1 C water to 7.2 C water (Tagatz 1961).

SALINITY - TEMPERATURE INTERACTION - Juveniles tested at 7.2 C to 26.7 C and 10 to 35 $^{o}/oo$ were tolerant to transfers between salt and fresh water at most temperature differences (Tagatz 1961).

ACCLIMATION - Davies (1970) found juveniles acclimated more slowly than larvae but the temperature range for survival was much greater (4.4 to 35 C). Acclimation to lower temperatures required eight days, while acclimation to higher temperatures was "rapid."

OXYGEN - The behavior of juvenile striped bass 81 to 108 mm TL at low oxygen concentrations was described by Chittenden (1971). At a temperature range of 16 to 19 C, the following behaviors were observed:

Dissolved oxygen level	Response
1.81 ± 0.10 mg l^{-1}	Restlessness
1.28 ± 0.10 mg l^{-1}	Inactivity
0.95 ± 0.06 mg l^{-1}	Equilibrium loss
0.72 ± 0.04 mg l^{-1}	Death

Chittenden concluded that dissolved oxygen concentrations of 3.0 mg l^{-1} may be the minimum necessary for normal existence at temperatures near 16 to 19 C. Klyashtorin and Yarzhombek (1975) determined that dissolved concentrations of 4.0 to 4.5 mg l^{-1} are critical for continuation of standard metabolism in 0.2 to 22 g striped bass; dissolved oxygen concentrations less than this restrict motor activity, which leads to reduced feeding, increased energy used for respiration, and reduced growth rate. A laboratory study by Dorfman and Westman (1970) showed that juveniles respond to reduced oxygen concentrations below 2.0 mg l^{-1} by moving towards the surface of the test chambers. Survivors fed on brine shrimp at oxygen levels lethal to 30% of the test population. Eighty percent of striped bass acclimated at oxygen levels of 8.5 and 6.6 mg l^{-1} and temperatures of 20 and 25.6 C survived when transferred to oxygen concentrations of 2.0 and 3.0 mg l^{-1}. Complete mortality occurred when fish acclimated to 5.9 mg l^{-1} at 32.8 C were transferred to 2.4 mg l^{-1} at 32.8 C. Dorfman and Westman also observed that juveniles spent more time in water of higher oxygen concentration when placed in a

gradient. Apparently there is no instinctive ability to quickly recognize and avoid waters of low oxygen concentration. Average growth was significantly impaired by daily exposure to diurnal fluctuations of oxygen concentrations averaging less than 4.0 mg l^{-1}. The authors concluded that striped bass that are engulfed by - or that swim into - waters with oxygen concentrations as low as 0.5 mg l^{-1} can probably survive for at least five minutes at that concentration if given access to an area of higher oxygen concentration (above 3.0 mg l^{-1}). An average dissolved oxygen concentration of 4.5 mg l^{-1} will result in stunted growth, though most will survive (Dorfman and Westman 1970).

SUSPENDED SEDIMENTS - No information available.

pH - No information available.

TRANSPORT - Successful transport of juveniles was accomplished using agitator tanks filled with dechlorinated tap water containing one percent NaCl (10 ppt) and 0.25 ppm quinaldine. Fish metabolism can be slowed during transport by using MS222 at a concentration of 21 ppm; this procedure reduces chance of shock or injury (Harper and Jarman 1972).

3.1.6.3 Swimming Ability

Striped bass are not strong swimmers, and juveniles are unable to swim at velocities commonly sustained by many species for similar periods (Kruger and Brocksen 1978). Skinner (1974) reported 90% of 40 to 50 mm juveniles were able to swim up to six minutes against currents not exceeding 24 cm s^{-1}, while most were impinged on test screens at currents exceeding 49 cm s^{-1}. Juveniles 50 mm TL exhibited decreased swimming range with increased velocity (0 to 27 cm s^{-1}); the magnitude of area covered was directly proportional to fish size (Bowles 1976). All striped bass 127 to 178 mm tested in a flume resisted a current of 61 cm s^{-1}, and only one fish was impinged on test screens at a current of 84 cm s^{-1} (Kerr 1953). A maximum swimming speed of 60 cm s^{-1} was reported for a 240 mm striped bass (Painter and Wixom 1967, cited in Setzler et al. 1980).

3.1.6.4 Chemical Tolerances

Toxicity of pesticides, heavy metals, and pharmaceutical drugs on juvenile striped bass was summarized by Bonn et al (1976). The presence of toxic substances such as heavy metals and oils in water may increase the dissolved concentration levels necessary for survival, causing

lethal or sublethal (reduced growth) effects, and may decrease upper thermal tolerance limits (Dorfman and Westman 1970).

KEPONE - All juvenile striped bass collected from the nursery zone of the James River near Hopewell, Virgina, in 1977 exceeded the Kepone action level (0.3 ppm) with average concentrations of 0.99 ppm. The only specimen collected below the nursery zone was below the action level at 0.09 ppm. York River juveniles contained mean Kepone concentrations of 0.02 ppm (Loesch et al. 1977). In 1978, James River juveniles, and those present in the Chickahominy River (a tributary), contained concentrations of 0.57 ppm (Johnson et al. 1978). Kepone concentration per unit body weight may reach a saturation level early in development, and further increases in juvenile Kepone body burden may be proportional to growth (Johnson et al. 1978).

CHLORINE - The estimated incipient LC_{50} concentration to total residual chlorine (TRC) was 0.04 ppm for 30-day-old juveniles; those surviving sustained gill and pseudobranch damage at TRC concentrations between 0.21 ppm (71 minutes) and 2.36 ppm (7 minutes) (Middaugh et al. 1977).

AMMONIA - Juveniles 20 to 73 mm TL were tested by Hazel et al. (1971) in a static system to determine the toxicity of undissociated ammonia. Median tolerance limits (TL_m) of NH_4PH at 96-hour exposures were:

Salinity	15 C	23 C
Freshwater	2.8 mg l^{-1}	1.9 mg l^{-1}
11 $^o/oo$	2.8	2.1
33 $^o/oo$	2.0	1.5

HYDROGEN SULFIDE - Striped bass kills in Casquiney Straight, California, were blamed on production of H_2S as a result of anaerobic conditions in shallow bays from low tides and high temperatures (Silvey and Irwin 1969, cited in Setzler et al. 1980).

CADMIUM - Juveniles exposed to cadmium (CADCL) for 30 to 90 days in concentrations of 0.5, 2.5, and 5.0 ppb were allowed to recover for 30 days in running seawater. Exposures caused changes in gill-tissue respiration and a slight drop in liver AAT and GGPdH after the recovery period (Dawson et al. 1977).

MERCURY - Juveniles exposed to mercury chloride for 30 to 120 days at concentrations of 1.0, 5.0, and 10.0 ppb were allowed to recover for 30 days in running seawater. Exposures caused changes in gill-tissue respiration (Dawson et al. 1977).

TRICON OIL SPILL ERADICATOR - This substance was toxic to striped bass at 10 ppm after 48 hours, but no stress was observed at 5 ppm (Chadwick 1960).

BENZENE - Sublethal concentrations increased the respiratory rate after exposure of 24 hours, and those exposed to 10 ppm for longer periods exhibited a narcosis that was reversible when fish were placed in freshwater and held longer than six days (Brocksen and Bailey 1973). Acute toxicity (LC_{50}) of benzene to 6 g bass is 6.9 ppm at 24 hours and 5.8 ppm at 96 hours (Benville and Korn 1977). Juvenile striped bass 18 cm SL exposed to concentrations of 3.5 and 6.0 ppb for four weeks exhibited feeding behavior aberrations (Korn et al. 1976). Initial reaction to low concentrations was pronounced hyperactivity. Fish exposed to 3.0 ppb consumed only 50% of their food ration, and fish exposed to 6.0 ppb attempted to feed but could not locate and consume their ration. After four weeks, feeding success improved; fish exposed to low concentrations fed normally while high concentration fish consumed 50% of their ration. All fish exposed to benzene exhibited decreases in wet weight, dry weight, and percent fat (Korn et al. 1976).

Static bioassays were used to determine the acute toxicities of toluene, ethylbenzene, p-xylene, m-xylene, and o-xylene on striped bass. The aromatic solubilities ranged from 180 to 1400 ppm, high enough to be lethal to striped bass. The following results were obtained from tests on 6 g striped bass:

M-XYLENE - LC_{50} = 9.2 ppb at 24 and 96 hours
O-XYLENE - LC_{50} = 11.0 ppb at 24 and 96 hours
P-XYLENE - LC_{50} = 2.0 ppb at 24 and 96 hours
TOLUENE - LC_{50} = 7.3 ppm at 24 and 96 hours
ETHYLBENZENE - LC_{50} = 4.3 ppm at 24 and 96 hours

(Benville and Korn 1977).

3.1.6.5 Pressure

No information available.

3.1.7 Life History - Adults

3.1.7.1 Longevity

Little information is available on the average life expectancy of striped bass. Commercial fisheries typically employ nets with mesh sizes allowing maximum catch efficiency; consequently, "jumbo" striped bass are rarely captured. Merriman (1941) reported an adult 29 to 31 years old weighing 29.5 kg caught in Rhode Island. An age class XV adult with a fork length of 111.4 cm was captured in waters offshore North Carolina (Holland and Yelverton 1973).

3.1.7.2 Nutrition and Growth

FEEDING - Members of a school normally feed at about the same time (Raney 1952), apparently following and feeding on schools of fish (Scofield 1928). Feeding intensity varies with season and time of day. Feeding is most intense just after dark and again just before dawn (Raney 1952). Adult stripers remain active and opportunistic feeders during winter, feeding on a variety of fish and invertebrates (Table 3.1-3) (Holland and Yelverton 1973). Adults feed heavily during their upstream migration, but fasting occurs just before and during spawning; prey items during migration are mostly adult alewives and blueback herring (Hassler and Hill 1981). Striped bass on the spawning grounds in the Weldon area of the Roanoke River feed on unidentified minnows, golden shiners, immature blueback herring, and gizzard shad (Hassler and Hill 1981). Major food items depend on availability in any given habitat; some investigators believe striped bass select soft-rayed fishes (Ware 1971, Manooch 1973). The size of the forage fish consumed is dependent on striped bass size and is represented by the equation

$$Y = 0.22X - 0.25,$$

where X is striped bass length (TL) and Y is forage fish length (TL) (Manooch 1973). During summer, 92% of striped bass collected in Albemarle Sound had consumed fish; clupeid species were the dominant forage fish. By fall, clupeid and engraulid species reached maximum occurrence in the diet (64%), with bay anchovy comprising 37.7% of fish consumed. During winter, invertebrates became more important in the diet; by spring, blue crabs were the major prey item (Manooch 1973).

GROWTH - Annual growth rates for striped bass populations residing in waters along the southeast Atlantic coast average approximately 100 mm yr^{-1} for the first several growing seasons (Table 3.1-4). Rate of growth decreases with increased age of fish. Data in Table 3.1-4 suggest increased growth rates at lower latitudes, probably due to warmer temperatures and prolonged growing season.

METABOLISM - No information available.

3.1.7.3 Hardiness

No information was available on the hardiness of adult striped bass to changes in salinity, temperature, acclimation, suspended sediments, and pH.

SALINITY - TEMPERATURE INTERACTION - Adults tested at 7.2 to 26.7 C and 10 to 35 $^{o}/oo$ were tolerant to transfers between salt and fresh water at most temperature differences (Tagatz 1961).

OXYGEN - Striped bass avoid waters of 44% or less oxygen saturation, and can tolerate higher temperatures when water is oxygen-saturated than under conditions of reduced oxygen (Meldrim et al. 1974).

TRANSPORT - Adult stripers were successfully transported for 15.5 hours in 125 gallon tanks; water contained 2 ppm quinaldine, 0.4% NaCl, and a little antifoam-A (Dow) (Schoumacher 1969).

3.1.7.4 Swimming Ability

Adult striped bass tagged in the Cooper River, South Carolina, exhibited long distance swimming speeds averaging 1.8 to 4.8 km h^{-1} (17.9 to 134.1 cm s^{-1}) (Curtis 1976).

3.1.7.5 Chemical Tolerances

KEPONE - Adults collected in the James River, Virginia, in March 1978 contained Kepone concentrations ranging from non-detectable levels to 3.91 ppm; 54.4% of the males and 18.1% of the females had Kepone levels exceeding the action level (0.3 ppm). Five of the six contaminated males and two of the four contaminated females were less than age III and probably resident (pre-migratory) fish. The others below the Kepone action level were believed to have been recent arrivals (ages IV to VI) (Johnson et al. 1978).

Table 3.1-4. Annual growth rates (mm) of striped bass populations (Atlantic race) in river systems along the Atlantic coast. Age class I values are based on calculated fork lengths unless otherwise indicated (after Setzler et al. 1980).

RIVER SYSTEM	AGE CLASS I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	SOURCE(S)
Delaware River	99	116	101	111	100	100	78	87	74	50	73	53				Bason (1971)
Roanoke River																
Males (1963-5)			69	41	38	48	43	38	-	-	-					Hassler and
Females (1963-5)			-	51	30	58	48	20	53	18	20					Hill (1981)
Offshore North Carolina			57	151	49	70	83	106	62	50	37	9	24	63	39	Holland and Yelverton (1973)
Pamlico River and Sound			54	82	31	22	58	54	-	32						Marshall (1976)
Cape Fear River				112	100	67	73	120								Fischer (1980)
Santee-Cooper system	213*	186	104	79	73	69	43									Stevens (1958)
Cooper River	170	111	112	97	68	99	120									Curtis (1978)

* Total length

ACID RESIN SOAPS - A spill of black liquor (acid resin soaps) at Roanoke Rapids entered the Roanoke River in a concentration three times lethal strength, causing a massive striped bass kill on 21 April 1963 (Smith and Bayless 1963). Large numbers of adult striped bass were killed on the spawning grounds in the Weldon area; those not killed moved downstream just ahead of the contaminated water, which eventually dissipated 115 river miles below the spill area seven days later (Trent and Hassler 1968).

3.1.7.6 Pressure

No information available.

3.1.8 Behavior

3.1.8.1 Juvenile Migration and Local Movement

Local distributions and movements of juvenile striped bass in river systems north of North Carolina were summarized by Hardy (1978) and Setzler et al. (1980). Juveniles may frequent deeper portions of rivers, causing difficulties in locating nursery areas (Hawkins 1979). Refer to Section 3.1.2.4 for a brief review of general trends in distribution.

DELAWARE RIVER ESTUARY - Juveniles 17 to 389 mm FL occurred from March through November at 4.0 to 30.0 C and 0 to 6.4 $^{o}/oo$ salinity. Some were located upstream, but most utilized lower and middle sections of tidal creeks as nursery areas. Some striped bass juveniles may overwinter in tidal creeks (Smith 1971).

ALBEMARLE SOUND AREA - Juveniles utilize the western end of Albemarle Sound during summer months at salinities 0 to 7 $^{o}/oo$. Use of the lower Roanoke River, Middle River, and Cashie River as nursery grounds is negligible (Hassler and Hill 1981).

TAR-PAMLICO RIVER SYSTEM - In 1978, juveniles ranged from 35 to 165 mm in length; 88% were captured in July. Areas of capture include Hardee Creek in the Tar River to Pungo Creek in the Pungo River, with highest catches occurring in Broad and South Creeks. Over 70% of juveniles were collected over sand bottoms and near grass beds (Hawkins 1979).

NEUSE RIVER - Four juveniles 65 to 85 mm long were caught by beach seine below New Bern during July and August 1978 (Hawkins 1979).

Table 3.1-5. Nursery areas of juvenile striped bass (Atlantic race).

RIVER SYSTEM	LOCATION	SOURCE(S)
Delaware River Estuary	Some juveniles are found upstream but most are found in lower and middle sections of tidal creeks	Smith (1971)
Roanoke River	Primarily western end of Albemarle Sound from the Roanoke River mouth to 15 miles east at salinities 0 to 7 $^{o}/oo$	W.W. Hassler (1981, pers. comm.)
Tar-Pamlico River system	Hardee Creek in Tar River stretching to Pungo Creek in the Pungo River at salinities 0 to 4.5 $^{o}/oo$; major areas: Broad Creek, South Creek	Hawkins (1979)
Neuse River	Downstream from New Bern	Hawkins (1979)
Northeast Cape Fear River	Lane's Ferry to river mouth; also Turkey Creek	Sholar (1977b)
Altamaha River	River Mile 0 to 14; estuary used as primary nursery zone	Smith (1968)
St. Johns River	Perhaps near mouth of the Oklawaha River	Barkaloo (1970)

NORTHEAST CAPE FEAR RIVER - During 1975-76, young-of-the-year striped bass were collected from Lane's Ferry to the river mouth, with highest concentrations occurring in January in deeper water (Sholar 1977b). Juveniles were collected October through March and again from May through August; individuals captured in Turkey Creek in May were all age II, immature males 268 to 280 mm FL (Sholar 1977b). Only one striped bass juvenile (42 mm FL) was caught during 1979 in July (Fischer 1980).

CAPE FEAR RIVER - Two juvenile striped bass were caught during July 1977 having a mean fork length of 37 mm (Fischer 1980). During spring 1978, striped bass larvae less than 25 mm SL were collected in average concentrations of 13 larvae per 1000 m^3 in upstream areas of the estuary under conditions of high freshwater flow (J.O. Hackman 1981, pers. comm.).

OGEECHEE RIVER - Striped bass, ages I, II, and III, were tagged and released at King's Ferry (RM 20); some were recaptured upstream as far as River Mile 100 (July), but most were recaptured within 10 miles of the stocking site (Geddings 1973). Striped bass comprised seven percent of the total sport catch by number from the estuarine portion (≥ 0.5 $^{o}/oo$); 66% were less than 381 mm TL. None were caught in this area during March through July, and none were collected in riverine sections (< 0.5 $^{o}/oo$) during the same period (Geddings 1973).

3.1.8.2 Adult Migration and Local Movement

OFFSHORE NORTH CAROLINA - During 1969-70, 55.5% of striped bass collected in the ocean offshore North Carolina were captured from Cape Lookout to Cape Hatteras. During 1968-69 and 1970-71, 99% and 93% were collected from Cape Hatteras northward to the Chesapeake Bay mouth offshore (Holland and Yelverton 1973). All were collected exclusively in the inshore zone in 0 to 10 fathoms of water. The occurrence of striped bass in the ocean appears to be seasonal, mid-November through March. The inshore zone between Cape Henry, Virginia, and Cape Lookout, North Carolina, serves as the wintering grounds for the migratory segment of Atlantic coast striped bass populations. Three main groups of fish appear to congregate off the North Carolina coast from November through March: striped bass, which enter Albemarle and Pamlico Sounds (mostly small fish); fish from Chesapeake Bay (mixed sizes); and predominantly large ("jumbo") stripers which spend the summer from New Jersey northward (Holland and

ROANOKE RIVER - A small segment of the immature female population of Albemarle Sound usually migrates upstream in the spring for some distance above Williamston but not as far as the spawning grounds. Schooling behavior may be such that immature females tend to accompany adults upstream for a certain distance and then return to the Sound. The migratory population of the Roanoke River is mostly sexually-mature fish. Most males migrate upstream through Williamston in late March to mid-April whereas most females migrate between mid-April to mid-May (Trent and Hassler 1968).

NEUSE RIVER - Only one adult tagged and released in 1977-78 was recaptured. This adult was found 98 days after release just upstream from the mouth of the Trent River, approximately 10 km from the tagging site (Hawkins 1979).

NEW RIVER - No adults were captured in 1974 or 1975 (Sholar 1975).

WHITE OAK RIVER - No adults were captured in 1974, but three were collected in March 1975 in the lower portion of the river (Sholar 1975).

NORTHEAST CAPE FEAR RIVER - Adult striped bass were found throughout spring 1976 with greatest abundance in April (Sholar 1977b). No adults were captured in 1979; one adult tagged in the river was recaptured in the Cape Fear River (32 miles) (Fischer 1980).

CAPE FEAR RIVER - In 1978 and 1979, adults were found in the river from January through May with greatest abundance in January. Adults were captured as far upstream as Hood Creek, with the majority found just above or below the city of Wilmington in bays or oxbows (Fischer 1980). Nichols and Louder (1970) reported striped bass passing through Lock and Dam No. 2 near Elizabethtown.

COOPER RIVER - Two striped bass tagged and released in December 1974 migrated downstream to within 0.5 mile of Fort Sumter. None released after December exhibited seaward migration (Curtis 1975). Fish tagged in fall 1975 and spring 1976 exhibited the following local movements in the Cooper River: Average long distance traveling speeds varied from 0.4 to 3.0 miles per hour. Many investigated mouths of creeks and breaks in rice field dikes, and several spent considerable time in abandoned rice fields. Major movements upstream or

downstream were not correlated with tidal direction. Often fish were present in very shallow water - often three feet or less in rice fields. Most stripers established home ranges 300 to 400 yards near some physical structure such as pilings, docks, creek mouths, or depressions in the river bottom. These home ranges were not apparent during the spring spawning run (Curtis 1976).

SAVANNAH RIVER - Dudley et al. (1977) reported movements of striped bass adults in the Savannah River. Adults tended to move more when water was cooler. As a group they tended to move primarily during the afternoon and early evening while in the spawning area. There was a tendency for adults to move less at flood tide than at any other tide stage, and they seemed to move more on ebb tide than on flood tide. Movement was least during new moon. When spawning season ended, all stripers left the Little Back River and most proceeded upstream. Males and females departed at similar times. Two radio-tagged fish moved 240 km upstream in less than three weeks. None of the stripers tagged near Augusta, Georgia, in the autumn and winter of 1974-75 moved any great distance or exhibited movement patterns related to any obvious influence. Striped bass were found in the Augusta area both upstream and downstream from New Savannah Bluff Lock and Dam during summer, fall, and winter months, but none were found in the spring. Excessively warm ocean waters during summer may limit any seaward migration, thus causing the population to remain riverine. The Lower Savannah River reaches 26 C during July through September, and maximum temperature of marine waters reaches between 27 and 30 C (Dudley et al. 1977).

OGEECHEE RIVER - Most striped bass are caught in the estuarine portion ($\geq$0.5 ^{o}/oo) from July through March. Sport catch rates in this area are generally highest from September through January. Stripers are occasionally caught in upstream riverine areas (0.0 ^{o}/oo) beginning in January, with greatest catch rates occurring in April and May (Hall 1971, Hornsby and Hall 1981).

ST. JOHNS RIVER - Adult striped bass are found from Doctors Lake southward to Lake Monroe, and from the mouth of Oklawaha River - the largest tributary of the St. Johns River - to the Moss Bluff Dam (McLane 1955). Stripers are also fairly abundant some years in Black Creek, Croaker Hole in Little Lake George, and near the mouths of some tributary streams. Salinities range from 100 to 500 ppm in these areas. Stripers inhabit deep water in

deep holes and about the mouths of larger tributary streams. Sporadic catches also occur on shallow bars where they apparently congregate to feed on concentrations of surface schooling fishes such as anchovies, shad, silversides, and so forth. Sport fishing catches indicate local seasonal congregations during July, August, and September (McLane 1955).

3.1.8.3 Responses to Stimuli

LIGHT - The extent of positive phototrophism displayed by striped bass fry is directly related to the intensity of light, not to its wavelength. Fry are most attracted to light of moderate intensity and are unaffected by low intensity, but avoid light of high intensity (Braid 1977). Adults feed most actively just after dusk and again just before dawn (Raney 1952). Artificial light appeared to have a tranquilizing effect on fry held in aquaria at Weldon Hatchery, North Carolina (Tatum et al. 1966).

TEMPERATURE - Dorfman (1974) concluded from laboratory experiments that juvenile striped bass may be unable to discern lethal temperatures. Johnson et al. (1978) suggested that water temperature may be a factor in striped bass. During the winter of 1977-78, small striped bass (ages III and IV), which are normally endemic to inshore waters, moved offshore in response to extremely low water temperatures in North Carolina inland waters, similar to the winter of 1969-70 (Johnson et al. 1978).

OXYGEN - Striped bass will avoid waters of 44% or less oxygen saturation (Meldrim et al. 1974).

CURRENT - Juvenile striped bass orient into a water flow, with intensity of orientation increasing with increased velocity. Areas of high turbulence are avoided (Kerr 1953). Radio-tagged adults in the Chesapeake and Delaware Canal indicated variation in response to water flow based on flow direction. Adults oriented and maintained position in water flows opposite from their intended direction of movement; in currents flowing with their intended direction of movement, stripers swam or drifted with the current (Koo and Wilson 1972).

3.1.9 Population

3.1.9.1 Sex Ratio

ROANOKE RIVER - Females begin migration approximately two weeks later than males (Hassler and Hill 1981).

These authors determined sex ratios of year classes over a three-year period. The following results were obtained:

	AGE CLASS							
YEAR	II	III	IV	V	VI	VII	VIII	IX
1963	1:0	91:1	1:2.3	1:3.2	1:6.5	1:2.3	0:1	0:1
1964	1:0	1:0	3.1:1	1:4	0:1	1:3.5		
1965	-	333:1	2.6:1	1:2.5	0:1			

The overall sex ratios for each season were 3.3 males to one female in 1963, 6.7:1 in 1964, and 23.0:1 in 1965 (Hassler and Hill 1981).

OFFSHORE NORTH CAROLINA - During 1970-71, the male to female ratio was 1:7.5 (Holland and Yelverton 1973).

WHITE OAK RIVER - No males were captured in 1975 (Sholar 1975).

NORTHEAST CAPE FEAR RIVER - Male to female ratio was 2.5:1 in 1976 (Sholar 1977b).

CAPE FEAR RIVER - Males and females were captured in equal numbers in 1978; the sex ratio was 1:1.7 in 1979 (Fischer 1980).

3.1.9.2 Age Composition

ROANOKE RIVER - Age classes III and IV comprised 90% of the male striped bass population caught in commercial gill nets from 1963 to 1965; 85% of the female population was comprised of age classes IV and V (Hassler and Hill 1981).

ALBEMARLE SOUND - During 1974-75, striped bass ranged from age II to age XI with the age groups II, III, IV, and V comprising 89% of the sample (Table 3.1-6). The strength of the 1970 year class, first sampled in 1972 and dominating samples in 1972 and 1973, was diminished in strength as a result of mortality and probably fish selectivity. Ages II, III, and IV comprised 93% of the hook and line harvest in October, 1974; ages ranged from II to VII (Holland et al. 1975).

NEUSE RIVER - During 1976-77, striped bass ranged from age I to IX, with groups II, III, and IV dominating catches (Marshall 1977). During 1977-78, the 24 adults captured ranged from age class IV to IX (Hawkins 1979).

Table 3.1-6. Age composition (%) of striped bass populations (Atlantic race) in river systems within Region IV. M = males; F = female; C = sexes combined.

RIVER SYSTEM AND YEAR	SEX	AGE CLASS I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	SOURCE(S)
Roanoke River																	
1963	M		2	70	24	4	<1	<1	-	-							Hassler and Hill (1981)
	F		-	2	73	19	4	1	1	<1							
1964	M		1	80	16	3	-	<1									
	F		-	-	43	44	9	4									
1965	M			68	26	6	-										
	F			<1	54	31	14										
Albemarle Sound																	
1975	C		17	21	26	25	5	3	2	1	0	<1					Johnson et al. (1977)
1976	C		4	43	16	24	9	2	1	<1	<1	-					
Albemarle Sound																	
July 1977 to June 1978	C		29	36	25	8	1										Johnson and Hassler (1980)
July 1978 to June 1979	C		29	37	15	13	5	1									Johnson and Hassler (1980)
Offshore NC																	
1968-71	C		4	13	2	9	12	9	9	13	7	9	8	3	2	<1	Holland and Yelverton (1973)
Pamlico River																	
1978	C		5	10	33	33	14	-	5								Hawkins (1979)

Table 3.1-6. Age composition (cont'd.)

RIVER SYSTEM AND YEAR	SEX	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	SOURCE(S)
		AGE CLASS															
Neuse-Trent system																	
1976, Fall	C	40	40	16	-	3	-	1									Marshall (1977)
1977, Spring	C		14	38	34	7	3	2	-	2							Marshall (1977)
1977, Fall	C				91	9											Hawkins (1979)
1978, Spring	C				15	15	8	31	8	8	8	8					Hawkins (1979)
White Oak River 1975	F			66				33									Sholar (1975)
Northeast Cape Fear River 1976	M		40	10	10	30	10										Sholar (1977b)
	F				25	25	0	50									
Cape Fear River 1978-79	C		2	7	29	42	5	9	4	2							Fischer (1980)
Cooper River July 1977 to June 1978	C	39	17	22	11	5	3	3									Curtis (1978)

WHITE OAK RIVER - Three females were collected in 1975; two were age class III and one was VII (Sholar 1977b).

NORTHEAST CAPE FEAR RIVER - In 1976, age classes of striped bass ranged from II to VII; ages II and V predominated (Sholar 1977b). Only two adults were captured in 1979: an age VI male and a female, age X (Fischer 1980).

CAPE FEAR RIVER - Stripers ranged from age IV to XI in 1978-79; ages IV and V predominated (Fischer 1980).

3.1.9.3 Size Composition

Male striped bass are smaller than females of similar age (Table 3.1-7).

3.1.9.4 Abundance and Population Status

Peak commercial landings from 1967 through 1976 have plummeted to new lows for the 1980s in North Carolina. South Carolina and Georgia have both declared the striped bass a game fish, thus making commercial fishing for stripers illegal. The abundance of Florida striped bass has remained at relatively low levels for years. Population status of Southeast striped bass stocks is not well-documented. Mark-recapture programs and creel census statistics seem to indicate that Southeast Atlantic coast populations are riverine and endemic. Population estimates of these stocks are lacking for many river systems.

The status of striped bass (Atlantic race) in river systems throughout Region 4 was estimated from responses to the Anadromous Fisheries Questionnaire by various State, Federal, and other agencies (Section 4). From these responses, it appears that many striped bass populations (41.2%) are in various stages of decline along the South Atlantic coast (Table 3.1-8). Those populations which are increasing are the result of intensive stocking programs by State and Federal agencies and protection of the stock by prohibiting commercial fishing. Factors possible important in contributing to the decline of certain populations are presented in Table 3.1-9.

ROANOKE RIVER - From 1957 through 1976, highly-significant differences have existed in abundance of young-of-the-year striped bass in Albemarle Sound; since 1976, a drastic

Table 3.1-7. Size composition (mean fork length in mm) of striped bass populations (Atlantic race) in river systems within Region 4. M = males; F = females; C = sexes combined.

RIVER SYSTEM AND YEAR	SEX	AGE CLASS I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	SOURCE(S)
Roanoke River																	
1963	M		361	439	465	488	551	579	627	-	-	-					Hassler and Hill (1981)
	F		-	470	521	546	610	650	671	709	729	742					
1964	M		353	419	467	516	-	610	640	813	-	-	-				
	F		-	444	503	546	597	650	668	775	767	838	965				
1965	M		343	414	457	513	-	610									
	F		-	457	500	541	594	-									
Offshore NC																	
1968-71	C		314	371	522	571	641	724	830	892	942	979	988	1012	1075	1114	Holland and Yelverton (1973)
Pamlico River																	
1978	C		367	419	468	544	567	-	743								Hawkins (1979)
Neuse-Trent system																	
1976, Fall	C	370	424	465	-	629	-	630									Marshall (1977)
1977, Spring	C		362	427	456	516	583	558	-	660							Marshall (1977)
1977, Fall	C					542	580										Hawkins (1979)
1978, Spring	C				485	533	587	620	748	745	895	785					Hawkins (1979)
White Oak River																	
1975	F			398				712									Sholar (1975)
Northeast Cape Fear River																	
1976	M		275	346	340	560	564	-									Sholar (1977b)
	F		-	-	471	589	-	752									

Table 3.1-7. Size Composition (cont'd.).

RIVER SYSTEM AND YEAR	SEX	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	SOURCE(S)
		AGE CLASS															
Cape Fear River 1978-79	C[1]			378	490	590	657	730	850								Fischer (1980)
Cooper River 1978	C[2]	173	284	396	493	561	660	780									Curtis (1978)
Albemarle Sound 1976-77	C	298	335	410	474	539	604	650	741	800	772						Johnson and Hassler (1980)
1977-78	C		328	365	440	523	577										
1978-79	C		330	367	439	516	552	598									

[1] Values are median of the range.

[2] Total length.

Table 3.1-8. Status of striped bass (Atlantic race), Morone saxatilis, in river systems within Region 4 based on questionnaire responses to question VI-2. S = response from marine representative; F = response from freshwater representative.

RIVER SYSTEM	STATUS
NORTH CAROLINA	
Currituck Sound	
Albemarle Sound	Declining (SF)
North R.	
Pasquotank R.	
Little R.	
Perquimans R.	
Yeopim R.	
Chowan R.	Declining (S), Probably never present (F)
Meherrin R.	Stable or declining (S)
Roanoke R.	Declining (SF)
Cashie R.	
Scuppernong R.	
Alligator R.	
Pungo R.	
Pamlico R.	Increasing (S)
Tar R.	Increasing (SF)
Neuse R.	Stable (S), Declining (F)
Trent R.	
North R.	
Newport R.	
White Oak R.	Declining (S)
New R.	Threatened or extirpated (S)
Cape Fear R.	Stable or declining (SF)
Northeast Cape Fear R.	Stable or declining (SF)
Black R.	
Pee Dee R.	Declining (F)
SOUTH CAROLINA	
Waccamaw R.	Not known (S), Stable (F)
Little Pee Dee R.	Stable (S)
Great Pee Dee R.	Not known (S), Stable (F)
Black R.	Not known (S), Stable (F)
Santee R.	Not known (S), Stable (F)
Cooper R.	Not known (S), Stable (F)
Ashley R.	Not known (S), Stable (F)
Edisto R.	Not known (S), Stable (F)
Ashepoo R.	Not known (S), Stable (F)
Combahee R.	Not known (S), Stable (F)
Sampit R.	Not known (S), Stable (F)
Salkehatchie R.	Stable (F)
Savannah R.	Not known (S), Stable (F)
Lynches R.	Not known (S)

Table 3.1-8. Striped bass, Atlantic race (cont'd.).

RIVER SYSTEM	STATUS
GEORGIA	
Savannah R.	Declining (S), Not known (F)
Ogeechee R.	Declining (S), Not known (F)
Altamaha R.	Declining (S), Not known (F)
Oconee R.	Not known (F)
Satilla R.	Declining (S), Not known (F)
Ocmulgee R.	Not known (F)
St. Marys R.	Declining (S)
Chattahoochee R.	Increasing (F)
Flint R.	Increasing (F)
FLORIDA	
St. Marys R.	Declining (S), Stable (F)
Nassau R.	Declining (S), Stable (F)
St. Johns R.	Not known (S), Increasing (F)
Pellicer Cr.	Probably never present (S)
Moultrie Cr.	Probably never present (S)
Tomoka Cr.	Probably never present (S)
Hillsborough R.	Probably never present (S)
Suwannee R.	Probably never present (S)
Apalachicola R.	Probably never present (S)
Ocklockonee R.	Increasing (F)
Escambia R.	
ALABAMA	
Alabama R.	Increasing (SF)
Tombigbee R.	Increasing (S)
Perdido R.	Increasing (S)
Bon Secour R.	Increasing (S)
Fish R.	Increasing (S)
Magnolia R.	Increasing (S)
Dog R.	Increasing (S)
Fowl R.	Increasing (S)
Tennessee R.	Increasing (F)
Chattahoochee R.	
Coosa R.	Increasing (F)
Tallapoosa R.	Increasing (F)
MISSISSIPPI	
Pascagoula R.	
Tchouticabouffa R.	Increasing
Biloxi R.	Increasing
Wolf R.	Increasing
Jourdan R.	Increasing
Pearl R.	Increasing

Table 3.1-8. Striped bass, Atlantic race (cont'd.).

RIVER SYSTEM	STATUS
LOUISIANA	
Pearl R.	Increasing
Bayou LaCombe	Increasing
Tchefuncte R.	Increasing
Tangipahoa R.	Increasing
Tickfaw R.	Increasing
Amite R.	Increasing
Mississippi R.	Increasing
Atchafalaya R.	Increasing
Vermillion R.	Not known
Mermentau R.	Increasing
Calcasieu R.	Increasing
Sabine R.	Increasing

Table 3.1-9. Factors possibly important or very important to the decline of certain populations of striped bass (Atlantic race), *Morone saxatilis*, within Region 4 based on questionnaire responses to question I. S = response from marine representative; F = response from freshwater representative; C = response from other agencies.

NORTH CAROLINA

- Channelization (C)
- Dams and impoundments (FC)
- Industrial water intakes (FC)
- Location of industrial discharges (FC)
- Chemical pollution (F)
- Turbidity (F)
- Low oxygen levels (F)
- Sewerage outfalls (C)
- Inadequate control of water release from dams (FSC)
- Reduction in nursery areas (F)
- Poor food availability (F)
- Spawning areas too accessible to fishermen (FC)
- Poor water quality (FSC)

SOUTH CAROLINA

- Dams and impoundments (S)
- Inadequate fishway facilities (S)
- Reduction in spawning habitat (S)
- Poor water quality (S)

GEORGIA

- Channelization (S)
- Dredge and fill projects (S)
- Location of industrial discharges (S)
- Chemical pollution (S)
- Thermal effluents (S)
- Reduction in spawning habitat (S)
- Poor food availability (S)
- Spawning areas too accessible to fishermen (S)
- Poor water quality (S)

FLORIDA

- Channelization (F)
- Dredge and fill projects (F)
- Bulkheading (F)
- Dams and impoundments (F)
- Location of industrial discharges (F)
- Chemical pollution (F)
- Low oxygen levels (F)
- Sewerage outfalls (F)
- Reduction in spawning habitat (F)
- Reduction in nursery areas (F)
- Poor water quality (F)
- Agricultural drainage (F)

downward trend has been observed (Hassler and Hill 1981). Abundance of juveniles in Albemarle Sound nursery areas was the lowest on record in 1978 (Johnson and Hassler 1980).

TAR-PAMLICO RIVER SYSTEM - No young striped bass had been reported since 1974 when the stocking program by the North Carolina Wildlife Resources Commission was terminated. In 1978, however, 37 juveniles were collected from this river system, indicating a successful spawn (Hawkins 1979).

NEUSE RIVER - 1978 was the first year in which North Carolina river survey crews recorded capture of juvenile striped bass, indicating a successful spawn. The natural population of adult striped bass in the Neuse was very low in 1978 (Hawkins 1979).

OGEECHEE RIVER - During two studies of striped bass in the Ogeechee River, Georgia (Holder and Hall 1975, Hornsby and Hall 1981), a total of 117,099 advanced fingerlings with micro-magnetic tags were released from 1974 to 1978. Of these, 34,988 were Hudson/Roanoke River stock, 18,288 were Savannah/Santee-Cooper River stock, and 63,823 were Savannah/Ogeechee River stock. In the fall of 1976, hatchery-reared fish comprised six to 15% of the 1976 year class (YOY) and 29% of the 1975 year class. Stocked fish also comprised a minimum of seven percent of all sizes of striped bass in the Ogeechee River and a minimum of 20% of all harvestable-sized stripers. The stocking of 34,988 advanced fingerlings increased the number of 1975 year class recruits a minimum of 38%, and the stocking of 18,288 fish increased young-of-the-year recruits a maximum of six to 18%. In the fall of 1976, the estimated numbers of young-of-the-year, age 1+, and age 2+ and older striped bass in the river were 95,000-264,000, 29,000 and 11,000 respectively (Hornsby and Hall 1981, revised).

3.1.9.5 Factors Affecting Reproduction and Recruitment

Viability of spawned eggs and survival of larvae are two important factors in determining year class success. From 1960 through 1974, the viability of Roanoke River striped bass eggs ranged from 79.74 to 96.20%; decreasing egg viability began in 1975 and reached an all-time low (43.39%) in 1980 (Hassler and Hill 1981). The North Carolina Wildlife Resources Commission is currently conducting a study to determine causes of mortality; pesticides and organic toxicants

are suspected (Hassler and Hill 1981). In the Roanoke, the optimum water temperature for successful hatch and survival is 17 to 18 C. High egg viability occurs at higher water temperatures (18.8 to 20.4 C) but survival of larvae has been very low under those circumstances (Hassler and Hill 1981).

Viability of spawned eggs is also a concern to the recreational striped bass fishery in Santee-Cooper Reservoir. Congaree River supplies 95% of the eggs spawned in the fishery; in 1961, 93% of the eggs were viable. However, due to physical characteristics of Congaree River and location of spawned eggs, only 41.5% were expected to hatch. Wateree River contributes only five percent of the eggs spawned each year; viability was 70% but only 46% were expected to hatch (May and Fuller 1965).

Low to moderate flows in the Roanoke River favor striped bass abundance, while high discharge rates are unfavorable to the formation of strong year classes. Hassler and Hill (1981) determined that at low flows (5,091 to 9,741 cfs), strong year classes were formed in 1956, 1959, 1961, 1967, 1970, 1975, and 1976. Weak year classes occurred in 1956, 1957, 1958, 1971, 1972, 1973, 1978, 1979, and 1980 when river flow averaged from 10,260 to 31.750 cfs. High river discharge probably serves to carry eggs and larvae into lower river swamps or into higher salinity waters beyond the nursery areas, lowering survival (Hassler and Hill 1981).

Density-independent mortality, caused by loss of young in water diversions, and flow rates, which serve to transport young to nursery areas, are major factors in regulating the striped bass population size in the Sacramento-San Joaquin Estuary, California (Stevens 1977).

The relationship between the estimated number of striped bass eggs spawned in the Roanoke River and the mean number of striped bass young-of-the-year collected in Albemarle Sound from 1961 to 1980 was non-significant, indicating no correlation between the number of eggs spawned and subsequent abundance of young-of-the-year striped bass (Hassler and Hill 1981).

Heinle (1976) suggested a link between cold winters and strong year class production in Chesapeake Bay; however, any relationship of this type for Albemarle Sound striped bass was not apparent in Hassler and Hill's (1981) study.

3.1.9.6 Mortality

FISHING MORTALITY - In the ocean offshore North Carolina, the mean total reduction in striped bass stocks from 1968 through 1971 fishing seasons was 24.3% and mean reduction per month due to fishing was 3.6%. The calculated annual fishing mortality rate for striped bass tagged in the ocean off North Carolina and recaptured from North Carolina to Maine was 35% (Holland and Yelverton 1973). The overall exploitation rates for Albemarle Sound striped bass were 26% for 1965 and 24.5% for 1966 (Hassler et al. 1966, 1967). Fishing mortality rates for years 1956 through 1980 in Albemarle Sound and Roanoke River are presented in Table 3.1-10. In the Ogeechee River, Georgia, exploitation rates of the striped bass population from 1 March 1977 to 28 February 1978, was estimated to be eight percent; 60% of striped bass harvested during that period were 1975 year class or older fish (Hornsby and Hall 1981).

NATURAL MORTALITY - Total mortality of Ogeechee River stocks was reported to be 0.504 from 1 March 1977 to 28 February 1978; based on this total mortality figure, natural mortality was estimated to be 42% (Hornsby and Hall 1981).

IMPINGEMENT - Survival of striped bass eggs impinged - or caught - on traveling screens of water intake structures is related to impingement time. Eggs may survive impingement for up to six minutes at water velocities less than 24 cm s^{-1} but the survival rate and hatching success of impinged eggs are highly variable (Skinner 1974). Mortality of striped bass larvae 19 to 38 mm long impinged on the screens of a test flume was 100%. Survival of larvae and yearling striped bass even for short periods is very low; therefore smaller striped bass may have a higher survival rate if allowed to pass through a power plant with its subsequent thermal shock (Kerr 1953). Minimal mechanical damage of two-week-old, four to six mm larvae is encountered passing through a typical power plant cooling condensor tube; observed mortalities are attributal to thermal exposure (Coutant and Kedl 1975, cited in Setzler et al. 1980).

3.1.10 Predator-Prey Relationships

Chaborus spp. prey upon sac-fry (Tatum et al. 1965). Direct information is lacking, but Setzler et al. (1980) suggested large bluefish and weakfish probably prey on small striped bass in the Atlantic, and adult and juvenile white perch probably consume large numbers of larvae in inland waters.

Table 3.1-10. Fishing mortality rates for striped bass populations in river systems along the South Atlantic coast.

RIVER SYSTEM	YEAR	PERCENT MORTALITY		SOURCE(S)
Albemarle Sound Area		Albemarle Sound	Roanoke River	Hassler and Hill (1981)
	1956	16.23	5.56	
	1957	13.17	6.45	
	1958	8.68	7.49	
	1959	15.08	11.84	
	1960	21.76	9.48	
	1961	16.61	7.25	
	1962	7.36	27.59	
	1963	17.81	9.18	
	1964	16.21	11.36	
	1965	13.21	13.81	
	1966	9.06	14.53	
	1967	3.75	20.18	
	1968	15.42	11.34	
	1969	4.89	14.02	
	1970	18.24	11.28	
	1971	9.97	22.33	
	1972	6.38	13.87	
	1973	5.42	6.44	
	1974	9.10	1.87	
	1975	-	-	
	1976	7.27	18.41	
	1977	6.89	8.68	
	1978	12.83	7.08	
	1979	7.79	8.57	
	1980	7.79	2.60	
Offshore North Carolina	1968 to 1971	35.0		Holland and Yelverton (1973)
Ogeechee River	3/77 to 3/78	8.0		Hornsby and Hall (1981)

3.1.11 Diseases

Setzler et al. (1980) presented an excellent literature review on the following diseases; parasites; fin rot disease; pasteurellosis; columnaris; Kudo cerebralis; epitheliocystis; pugheadedness, and blindness. During spring 1980, there were many reports of red sore disease affecting striped bass in the Roanoke River and Albemarle Sound. No young-of-the-year were collected which were afflicted with the disease, indicating lack of vulnerability to the causitive organism (Hassler and Hill 1981). Vitamin C deficiency caused a spinal deformity in fish held in raceways (Geddings 1973).

3.1.12 Exploitation

3.1.12.1 Gear

NORTH CAROLINA - Commercial gear utilized on the Roanoke River include anchor gill nets, "rock" drift gill nets, trotlines, fishing machines or wheels, hoop and fyke nets, rod and reel, and haul seines. Some stripers are also captured in herring nets and perch traps (Hassler and Hill 1981). Commercial fisheries on the Neuse River employ drift netting with a full range of mesh sizes upstream, and stake gill nets and a haul seine principally from New Bern downstream (Marshall 1977). Sport fishing on all North Carolina rivers involves natural and cut baits or artificial lures (Baker 1968, Marshall 1977). During the 1970s, commercial fishing offshore from Ocracoke Inlet to the Virginia line comprised a significant portion of total striped bass catches statewide. Offshore beach seines ranged from two percent in 1971 to 50.1% in 1973 of total statewide landings. Trawl catches ranged from 2.7% (1977) to 30.5% (1970), and offshore gill nets ranged from <0.1% (1974) to 6.7% (1977) of total statewide landings (M.W. Street 1981, pers. comm.).

SOUTH CAROLINA - Commercial fishing is illegal for striped bass. Sport fishermen troll or cast with artificial lures, or bottom-fish with cut herring or other cut bait (Ulrich et al. 1979).

GEORGIA - Commercial fishing is illegal for striped bass. Georgia sport fishermen use gear and techniques similar to striper fishermen in South Carolina. Ogeechee River fishermen use natural bait - shrimp, etc. - in the estuary (Hornsby and Hall 1981).

FLORIDA - No information available.

3.1.12.2 Fishing Areas

NORTH CAROLINA - In recent years, the Atlantic Ocean north of Ocracoke Inlet, Albemarle Sound, and the Manns Harbor area of Croatan Sound have been productive fishing areas for striped bass (M.W. Street 1981, pers. comm.).

ROANOKE RIVER - The commercial fishery extends 102 miles from the river mouth upstream to Scotland Neck Bridge. "Rock" drift gill nets are used almost exclusively in the Jamesville area (RM 18), and most anchor gill nets are used in the Williamston area. The Jamesville Haul Seine at River Mile 18 has not operated since 1973. Sport fishing occurs from the river mouth to Roanoke Rapids Dam (140 miles). Accessibility by boat is available at numerous sites. Most activity occurs in the Weldon area and is the most intensively fished area of the river (Hassler and Hill 1981).

NEUSE RIVER - The more popular sportfishing area is over the striped bass spawning grounds from Kinston to Seven Springs (Hawkins 1979). Most fishing in the New Bern area occurs from railroad and highway bridges (Marshall 1977). Commercial fisheries in the upper Neuse River involve gill nets between SR 1421 and SR 1449, and from the river mouth to the mouth of Pitchkettle Creek at SR 1449 (Marshall 1977, Hawkins 1979). Another popular sportfishing area is Flower's Gap between New Bern and Batchelors Creek (Hawkins 1979). The Trent River supports a recreational fishery below Pollocksville (Marshall 1977).

CAPE FEAR RIVER - Marine Fisheries regulations prohibit the retention of striped bass caught in nets in New Hanover County. The Lower Cape Fear River supports a small hook and line fishery (Fischer 1980).

SOUTH CAROLINA - Commercial fishing for striped bass is illegal. There are no restricted areas for the striped bass recreational fishery (Ulrich et al. 1979). Most effort is concentrated in the lower reaches of the Waccamaw-Pee Dee, Wando, Cooper, Ashley, Edisto, Ashepoo, and Combahee Rivers from October through December, and the upper reaches in the spring (Ulrich et al. 1979).

GEORGIA - Commercial fishing for striped bass is illegal; there are no restricted areas for the recreational fishery. Fishing activity is concentrated in the lower reaches of the Savannah, Altamaha, Satilla, and St. Marys Rivers in fall and spring. Another popular location is in the Ogeechee River near Mill Hill, and in Rockfish Creek and Orange Canal (Ulrich et al. 1979).

FLORIDA - No information available.

3.1.12.3 Fishing Seasons

No information available.

3.1.12.4 Effort

NORTH CAROLINA - Commercial landings of striped bass in North Carolina peaked during the period 1967 to 1976 (Table 3.1-11). Highest commercial landings occurred in 1970; 2,318,000 pounds of striper were landed, representing 1.6% of the total poundage of finfish landed in the State (Table 3.1-12). Dockside value of the 1970 landing was $479,000 (Table 3.1-13) which represented over 10% of the total finfish dockside value for that year (Table 3.1-14). From December 1966 to June 1967, 12,720 stripers were captured by dip, bow, and skim nets; 15,136 were captured by anchored gill nets; and 1,905 were taken by drift gill nets (Baker 1968). Following is a listing of numbers of striped bass taken by special devices during the same period:

Chowan River	4,113
Roanoke	19,285
Albemarle Sound	1,856
Tar River	1,121
Pamlico River	2,051
Neuse River	1,121
Northeast Cape Fear River	68
Cape Fear River	128
Lumber River	0
Pee Dee River	0

(Baker 1968). The commercial fishery on the Roanoke River was reviewed by Hassler and Hill (1981). From 1960 to 1980, the major catches occurred at River Mile 30 (Williamston), comprising 46.5% of the total catch, and Jamesville (RM 18) which comprised 37.84% of the total catch. Commercial catches upstream from River Mile 70 were less than three percent of annual Roanoke River landings from 1960 to 1980. Hassler and Hill reported landings by gear type from 1966 to 1980:

Table 3.1-11. Striped bass landed (thousands of pounds).

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA	TOTAL
1939	339	0	.	0	.	.	.	.	339
1940	540	.	.	.	.	.	.	.	540
1945	609	1	.	.	.	.	.	.	610
1950	797	.	.	.	.	.	.	.	797
1951	702	.	.	.	.	0	.	.	702
1952	647	.	.	.	.	.	.	.	647
1953	757	.	.	.	.	.	.	.	757
1954	1122	.	.	.	.	.	.		1122
1955	736	.	.	.	.	.	.	.	736
1956	764	.	1	.	.	.	.	.	765
1957	597	.	1	.	.	.	.	.	598
1958	1096	.	1	.	.	.	.	.	1097
1959	872	.	1	.	.	.	.	.	873
1960	782	.	1	1	.	.	.	.	783
1961	550	.	1	.	.	.	.	.	551
1962	747	.	1	.	.	.	.	.	748
1963	736	.	1	.	.	.	.	.	737
1964	714	.	3	.	.	.	.	.	717
1965	434	.	2	.	.	.	.	.	436
1966	653	1	1	.	.	.	.	.	654
1967	1817	.	1	.	.	.	.	.	1818
1968	1912	2	.	.	.	.	.	.	1914
1969	1568	.	1	.	.	.	.	.	1569
1970	2318	.	2	.	.	.	.	.	2320
1971	1449	.	2	.	.	.	.	.	1451
1972	1261	.	5	.	.	.	.	.	1266
1973	1752	.	5	.	.	.	.	.	1758
1974	1016	.	.	.	.	.	.	.	1016
1975	1303	.	.	.	.	.	.	.	1303
1976	1038	.	.	.	.	.	.	.	1038
1977	571	.	.	.	.	.	.	.	571
1978	699	.	.	.	.	.	.	.	698
1979	614	.	.	.	.	.	.	.	614
1980	473	.	.	.	.	.	.	.	473

Table 3.1-12. Pounds landed (%) of striped bass in the total commercial catch of finfish by state.

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA
1939	0.16	0.02	.	0.00	.	.	.	.
1940	0.34	.	.	.	.	.	.	.
1945	0.34	0.03	.	.	.	.	.	.
1950	0.51	.	.	.	.	.	.	.
1951	0.50	.	.	.	.	0.01	.	.
1952	0.29	.	.	.	.	.	.	.
1953	0.46	.	.	.	.	.	.	.
1954	0.58	.	.	.	.	.	.	.
1955	0.35	.	.	.	.	.	.	.
1956	0.27	.	0.14	.	.	.	.	.
1957	0.28	.	0.11	.	.	.	.	.
1958	0.40	.	0.10	.	.	.	.	.
1959	0.27	.	0.09	.	.	.	.	.
1960	0.32	.	0.03	0.00	.	.	.	.
1961	0.21	.	0.04	.	.	.	.	.
1962	0.46	.	0.05	.	.	.	.	.
1963	0.32	.	0.06	.	.	.	.	.
1964	0.34	.	0.45	.	.	.	.	.
1965	0.24	.	0.21	.	.	.	.	.
1966	0.29	0.00	0.06	.	.	.	.	.
1967	0.89	.	0.05	.	.	.	.	.
1968	0.92	0.02	.	.	.	.	.	.
1969	0.84	.	0.11	.	.	.	.	.
1970	1.60	.	0.19	.	.	.	.	.
1971	1.22	.	0.21	.	.	.	.	.
1972	0.81	.	0.47	.	.	.	.	.
1973	1.47	.	0.71	.	.	.	.	.
1974	0.55	.	.	.	.	.	.	.
1975	0.59	.	.	.	.	.	.	.
1976	0.50	.	.	.	.	.	.	.
1977	0.25	.	.	.	.	.	.	.
1978	0.26	.	.	.	.	.	.	.
1979	0.17	.	.	.	.	.	.	.
1980	0.15	.	.	.	.	.	.	.

Table 3.1-13. Dockside value of striped bass (thousands of dollars).

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA	TOTAL
1939	34	0	.	0	.	.	.	.	34
1940	59	.	.	.	.	.	.	.	59
1945	121	0	.	.	.	.	.	.	121
1950	165	.	.	.	.	.	.	.	165
1951	134	.	.	.	.	.	.	.	134
1952	121	.	.	.	.	.	.	.	121
1953	137	.	.	.	.	.	.	.	137
1954	188	.	.	.	.	.	.	.	188
1955	120	.	.	.	.	.	.	.	120
1956	119	.	1	.	.	.	.	.	120
1957	90	.	1	.	.	.	.	.	91
1958	197	.	1	.	.	.	.	.	198
1959	158	.	1	.	.	.	.	.	159
1960	125	.	1	1	.	.	.	.	126
1961	88	.	1	.	.	.	.	.	89
1962	120	.	1	.	.	.	.	.	121
1963	115	.	1	.	.	.	.	.	116
1964	117	.	1	.	.	.	.	.	118
1965	77	.	1	.	.	.	.	.	78
1966	100	.	1	.	.	.	.	.	101
1967	253	.	1	.	.	.	.	.	254
1968	385	1	.	.	.	.	.	.	386
1969	325	.	1	.	.	.	.	.	326
1970	479	.	1	.	.	.	.	.	480
1971	314	.	1	.	.	.	.	.	315
1972	358	.	1	.	.	.	.	.	359
1973	592	.	2	.	.	.	.	.	594
1974	393	.	.	.	.	.	.	.	393
1975	630	.	.	.	.	.	.	.	630
1976	523	.	.	.	.	.	.	.	523
1977	405	.	.	.	.	.	.	.	405
1978	623	.	.	.	.	.	.	.	623
1979	577	.	.	.	.	.	.	.	577
1980	435	.	.	.	.	.	.	.	435

Table 3.1-14. Dockside value (%) of striped bass in the total commercial catch of finfish by state.

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA
1939	2.24	0.04	.	0.00	.	.	.	.
1940	3.89	.	.	.	.	.	.	.
1945	3.24	0.07	.	.	.	.	.	.
1950	4.40	.	.	.	.	.	.	.
1951	4.17	.	.	.	.	.	.	.
1952	2.88	.	.	.	.	.	.	.
1953	3.84	.	.	.	.	.	.	.
1954	4.43	.	.	.	.	.	.	.
1955	3.01	.	.	.	.	.	.	.
1956	2.20	.	0.96	.	.	.	.	.
1957	1.97	.	0.75	.	.	.	.	.
1958	3.50	.	0.74	.	.	.	.	.
1959	3.06	.	0.61	.	.	.	.	.
1960	3.24	.	0.21	0.02	.	.	.	.
1961	2.03	.	0.33	.	.	.	.	.
1962	3.60	.	0.29	.	.	.	.	.
1963	2.62	.	0.38	.	.	.	.	.
1964	2.59	.	0.75	.	.	.	.	.
1965	1.52	.	0.26	.	.	.	.	.
1966	1.99	.	0.32	.	.	.	.	.
1967	5.27	.	0.36	.	.	.	.	.
1968	8.37	0.09	.	.	.	.	.	.
1969	6.43	.	0.21	.	.	.	.	.
1970	10.48	.	0.22	.	.	.	.	.
1971	7.17	.	0.19	.	.	.	.	.
1972	6.17	.	0.36	.	.	.	.	.
1973	6.86	.	0.83	.	.	.	.	.
1974	3.74	.	.	.	.	.	.	.
1975	5.09	.	.	.	.	.	.	.
1976	3.57	.	.	.	.	.	.	.
1977	2.48	.	.	.	.	.	.	.
1978	2.55	.	.	.	.	.	.	.
1979	1.76	.	.	.	.	.	.	.
1980	1.25	.	.	.	.	.	.	.

GEAR TYPE	CPUE	% CATCH
"Rock" drift gill net	11.95	17.0
Haul seine (1961-64, 1968-73)	5.85	2.7
Anchor gill net	3.47	70.2
Rod and reel	3.18	3.0
Fishing machine	1.62	1.6
Trotline	1.18	4.2
Herring gill net	0.12	0.4
Hoop net	0.04	1.5

Commercial landings in the Neuse River are insignificant compared to statewide landings. The commercial striped bass fishery may have been important at the turn of the century but has remained at very low levels for the last 20 years (Marshall 1977).

The recreational fishery for striped bass caught the following number of stripers in North Carolina rivers from April 1967 to March 1968:

Chowan River	16,702
Roanoke River	18,333
Albemarle Sound	19,991
Tar River	2,088
Pamlico River	1,401
Northeast Cape Fear River	114
Cape Fear River	601
Pee Dee	229

(Baker 1968).

SOUTH CAROLINA - Most rivers support a recreational fishery for striped bass. Effort is concentrated in fall and spring but occurs year round. October through mid-April is the period for greatest catch-effort. Effort is concentrated in lower reaches from October through December, disperses throughout rivers in January and February, and resumes in upper reaches March through mid-April (Ulrich et al. 1979).

GEORGIA - Sportfishing for striped bass is best from November to mid-March (Ulrich et al. 1979). Hornsby and Hall (1981) estimated the average annual effort and fishing success rate for the Ogeechee River from 1974 to 1978. In the estuary, striped bass fishing effort (9506.3 hours) was 63% of total angler hours fished representing an average success rate of 0.31 stripers h^{-1}, or 0.25 h^{-1}. In the freshwater areas during the same period, 321.6 angler hours for striped bass were estimated (0.8% of total) representing a

success rate of 0.46 fish h^{-1}, or 0.32 kg h^{-1} (Hornsby and Hall 1981).

There is no allowable level of foreign fishing for striped bass; incidental catches are not significant (Ulrich et al. 1979).

FLORIDA - No information available.

3.1.13 Protection and Management

3.1.13.1 North Carolina

Prior to 1967, sport and commercial catch records were obtained by the Albemarle-Roanoke Striped Bass Studies, and the State and Federal agencies compiled statistics on the commercial fisheries in Albemarle Sound and adjacent areas. The only data lacking concerning striped bass exploitation in this area were the catch and effort by sport fishermen in Albemarle Sound. A very successful Albemarle Sound sport creel census was initiated and continued until 1973 when the program was discontinued for lack of funds (Hassler and Hill 1981).

Present (1981) regulations prohibit use of bow nets in the Roanoke River and the sale of striped bass in Halifax County. Formerly, fishermen using bow nets in the upper river were allowed to keep 25 stripers per day when taken incidentally. To complicate the situation, a local law which allowed commercial sale of striped bass was enacted by the Legislature which prevailed over State fishing regulations which prohibited commercial fishing above Scotland Neck Bridge (U.S. Hwy 258). Consequently, striped bass captured in the Weldon area were legally marketed, encouraging area fishermen to exceed the legal creel limit. In addition, the North Carolina Wildlife Resources Commission hatchery at Weldon depended on bow-net fishermen to supply native stock for spawning purposes. All of these factors created a prominent commercial fishery for striped bass in its principal spawning area; bow nets are now prohibited from the river (Hassler and Hill 1981).

An eight year peak in record commercial catches (1967 to 1976) caused bitter controversy between resident and non-resident fishing crews on the Outer Banks and also between commercial and sport fishermen.

The National Park Service intervened, and the result was to allow commercial fishing priviledges to bonafide Outer Banks residents only. Other regulations described activities allowed for both sport and commercial fishermen. Access to the beach was allowed on weekends for haul-seining from October through March at Cape Point and on Hatteras (M.W. Street 1981, pers. comm.).

Trent and Hassler (1968) concluded that "the management techniques which are most feasible for increasing the value of sport and commercial striped bass fisheries in North Carolina appear to be 1) increasing the minimum size limit from 12 inches TL to 16 inches FL, and 2) enforcing regulations which restrict use of gill nets having mesh sizes under 4.75 inches stretched mesh."

3.1.13.2 South Carolina

The anticipated reduction in striped bass spawning runs in the Cooper River due to the Santee-Cooper Rediversion Project has resulted in the initiation of a striped bass stocking program by the Wildlife Freshwater Fisheries Division, South Carolina Wildlife and Marine Resources Department. Establishing and maintaining striped bass stocks in the Santee River is necessary to insure adequate brood stock for hatchery use. Adequate research funds must be made available to monitor natural populations as well as survival and growth of stocked fish. The magnitude and impact of the Santee River shad fishery on striped bass populations should also be studied (Ulrich et al. 1979).

Other information needed includes records on the recreational striped bass fishery - catch and number of participants. Population dynamics are not well-known in South Carolina rivers. Effects of environmental variables and man-induced changes to river systems on striped bass populations are not well understood (Ulrich et al. 1979).

3.1.13.3 Georgia

The Georgia Game and Fish Division studied the results of stocking striped bass fingerlings in the Ogeechee River (AFS - 11 - 4), and information was also collected on striped bass catches in the recreational fishery in the same river system (Ulrich et al. 1979).

The final report of this AFS project was presented by Hornsby and Hall (1981). The following information was summarized from this report. The abolishment of the legal length limit and increase in the creel limit for striped bass in March 1977 apparently had little effect on the size and number of striped bass harvested. Based on the low estimated exploitation rate (eight percent), there appears to be no problem with overharvest of striped bass at current levels of fishing pressure. The stocking of 126,830 hatchery-reared, advanced fingerling striped bass over a five-year period had no detectable impact on angler success in the estuarine portion of the Ogeechee River one year after stocking. Stocking fingerlings at rates as high as 46,383 per year could not be shown as increasing the size of the striped bass population. The effects of stocking were apparently masked by some factor or factors which caused the population to decline over the five-year period in spite of stocking efforts. Stocked fish were recruited to the population, however; in the fall of 1976, 20% of all harvestable-sized striped bass were of hatchery origin. Stocking efforts may have occurred at a time when the natural population was in a period of decline; fishing success probably would have been much lower had the stocking program been abandoned. To effect a dramatic change in the Ogeechee River population, stocking rates of advanced fingerlings would have to be on the order of 100,000 annually. Stocking replacement fry or fingerlings should be continued to compensate for striped bass broodfish removed from the Ogeechee and Savannah Rivers every year for hatchery operations. It appears that the present striped bass creel limit of six fish per day is reasonable and that size limits are not warranted at this time (Hornsby and Hall 1981).

Ulrich et al. (1979) suggested additional information needed for assessing the status of striped bass stocks in Georgia. Information on the catch and number of participants in the recreational striped bass fishery is lacking. Population dynamics are not well-known in Georgia waters. Effects of environmental factors such as stream flow rate, temperature and turbidity on various life stages, and man-induced changes such as stream channelization, are not well understood.

3.1.13.4 Florida

No information available.

3.2 Gulf Coast Striped Bass (*Morone saxatilis*)

3.2.1 Historical Significance

Very little information has been published about Gulf race striped bass. Populations of native striped bass were common to coastal streams along the Gulf of Mexico and were identified by Raney (1952), Raney and Woolcott (1955), McLane (1958), and Barkaloo (1970) as a race separate and distinct from striped bass found along the Atlantic seaboard. Most of the information contained in this section was obtained from cooperative State-Federal project proposals and annual or completion reports for these projects. Other information was obtained through memoranda and verbal reports. The only information on life history aspects of native striped bass is of the remnant population residing in the Apalachicola River, Florida. Additional information on Atlantic race stocking programs initiated by State and Federal agencies is also presented.

3.2.1.1 Florida

Gulf of Mexico (STB-G) striped bass were once common to river systems along the Florida Gulf coast. At present, only remnant populations exist in these drainages, the largest occurring in the Apalachicola River. This population of native striped bass was determined to be a distinct and separate race from Atlantic coast stocks in 1960 (Barkaloo 1970). The distribution of native striped bass in Florida waters was determined by Barkaloo (1961) through interviews with fishermen and examination of written reports. The following drainages contained native striped bass in 1960: St. Marks, Ochlockonee, Choctawhatchee, Yellow, Blackwater, Escambia, and Perdido Rivers; Bear Creek in Bay County, and the Intracoastal Waterway at Panama City (Barkaloo 1961).

The relatively large numbers of Gulf race striped bass present in the Apalachicola River provided a viable sport fishery prior to construction of the Jim Woodruff Lock and Dam in 1957 (Crateau et al. 1980); commercial catches of up to 1,200 pounds were landed from the Apalachicola River prior to 1953 (Barkaloo cited in McIlwain 1980a). For several years after the Jim Woodruff Dam was completed, young-of-the-year were caught in such large numbers that fishermen considered them trash fish. In 1960, however, data indicated the population was under stress. Intermittent sampling by the Florida Game and Freshwater Fish Commission and interviews with fishermen showed that sport catches

were less frequent and little reproduction occurred. Since that time, the native striped bass population has declined drastically, while fishery interest has remained high (Crateau et al. 1980).

Native striped bass in the Apalachicola River may be doomed to extinction due to a series of events that has occurred through the years. The primary spawning grounds in the Flint and Chattachoochee Rivers are presently inaccessible to stripers due to construction of dams. Pesticides used in agricultural areas of Florida, Georgia, and Alabama in the 1940s through the 1960s may have eliminated populations in smaller systems; the Apalachicola River has a greater flushing and dilution capacity, but pesticides may have been important in the decline of native Apalachicola stocks (Crateau et al. 1980, McIlwain 1980a). At present, the remnant population of native (Gulf race) striped bass may be threatened by the introduction of Atlantic race stripers, which have been stocked in the river proper and above the Jim Woodruff Dam since the 1960s.

Atlantic race (ATL) striped bass have been stocked in Florida Gulf coast waters since the mid-1960s and have successfully reestablished a striped bass sportfishery in the Apalachicola, Ochlockonee, and Escambia Rivers. Atlantic race stripers were stocked in the Choctawhatchee River system from 1968 through 1975 by the U.S. Fish and Wildlife Service. During those years, almost 3.7 million fish were planted in an accumulated density of 36.9 fish per acre (Wigfall and Barkaloo 1975). A striped bass spawning run was observed in Choctawhatchee River during the spring of 1975 (Smith 1975). The stocking program in the Apalachicola River was initiated in 1966 by stocking Atlantic race stripers into a tributary of Lake Seminole. Atlantic race stripers were introduced once directly into the Apalachicola River proper on 7 April 1976, when 33,600 fish were planted at Blountstown, Florida (Crateau et al. 1980).

Recently, some investigators have come to believe that the introduction of Atlantic race striped bass to Gulf coast waters may be only marginally successful due to habitat requirements and behavioral differences. Atlantic race striped bass are not adapted to the warmer temperatures of Gulf coast rivers, and many stocks have marine migrational requirements and behavioral patterns different from native stocks. Present research efforts have been directed toward the capture of native (Gulf race) brood stock so that future stocking programs can plant a strain naturally adapted to these river

systems. Gulf race striped bass stocking could become an important management tool in reestablishing or restoring Gulf coast populations to levels sufficient for supporting viable sportfisheries (Creteau et al. 1980).

3.2.1.2 Alabama

Little information is available concerning the distribution and abundance of native (STB-G) striped bass in Alabama waters. Prior to 1967, spawning runs of native striped bass occurred in several Alabama rivers. Historically, there is little evidence to suggest that native striped bass populations were large enough to support a significant fishery, although Alabama has reported commercial landings of stripers on several occasions. Locally important fisheries developed at Tallassee, Alabama on the Tallapoosa River; at Wetumpka, Alabama on the Coosa River; and in Mobile Bay, Mobile Delta, Perdido Bay, and tributaries of these estuarine waters (Shell and Kelly 1967). Large quantities of striped bass were purchased by seafood companies in Mobile, Alabama in the 1950s and early 1960s (Swingle 1968, cited in McIlwain 1980a). Stripers were last purchased commercially in 1963 (McIlwain 1980a).

Causes for the disappearance of native striped bass in Alabama rivers are not known. Shell and Kelly (1967) suggested that the physical and chemical nature of Alabama rivers may no longer be satisfactory for spawning, hatching, and survival of early life stages, although survival and growth of young striped bass were excellent with the exception of polluted areas.

The last significant run of native striped bass in Alabama waters occurred in Mobile Bay in 1961. By 1968, this population was nearly extinct, although the presence of stragglers indicated a very limited amount of successful spawning each year. Pollution in rivers near Mobile was suspected (Shell and Kelly 1968). The Mobile Bay population historically utilized the Alabama River as spawning grounds, but during summer 1969 a navigation dam at Clairborn on the lower river was closed. The few remaining spawners may have become landlocked above the dam since it was closed at a time when the adults should have been upstream on the spawning grounds (Swingle 1971). A small native striped bass run was noted in the Tallapoosa River in 1967 (Shell and Kelly 1968).

In 1967, research was initiated on the possibility of establishing a population of striped bass in Mobile Bay large enough to support a fishery. Obstructions to spawning areas were believed to preclude the establishment of a naturally-sustained population. Stripers stocked in the system were anticipated to grow to commercially-harvestable size (Shell and Kelly 1968). From 1974 through 1976, 1.2 million (ATL) striped bass fingerlings of four different strains were released into Alabama waters contiguous to the Gulf of Mexico. The four strains stocked were Cooper River, Nanticoke River, Roanoke River landlocked, and Roanoke River sea-run. Apparently these stocked fish are surviving and growing well, and a striped bass fishery is presently developing in Alabama coastal waters (Powell 1976).

3.2.1.3 Mississippi

In the 1960s native (STB-G) striped bass were found in all major river systems along the Mississippi Gulf coast. McIlwain (1967) determined native distribution based on verbal and written accounts. Native striped bass were reported from the Tchouticabouffa, Biloxi, Wolf, Jourdan, Pearl, and Tangipahoa Rivers, as well as the east and west branches of the Pascagoula River and its many tributaries (McIlwain 1967).

The Mississippi striped bass fishery reaches a peak during the 1930s, 1940s, and 1950s. Large catches of stripers ranging from two to eight pounds were common in the late 1950s. Most of these catches were taken by commercial fishermen with gill nets in the Pascagoula River, and the fish were sold to seafood companies in Mobile, Alabama. After 1957, no large catches of striped bass were reported, but a few large individuals were caught in the 1960s. The last known native striped bass caught in the Mississippi waters was a 15-pound mature female collected in Bluff Creek, a tributary of the West Pascagoula River (McIlwain 1980a).

Rebuilding of striped bass populations was initiated in 1969 with the stocking of Atlantic race striped bass of South Carolina origin. As a result of these continued stockings, large numbers of striped bass are caught in the lower reaches of coastal streams, generally in the spring and fall (McIlwain 1980a). These fish do not appear to be migrating into adjacent Mississippi Sound or Gulf waters (McIlwain 1974). Although sexually mature adults are captured each year there is no evidence that they are spawning in the wild (McIlwain 1980a).

3.2.1.4 Louisiana

The western-most range of native striped bass in the Gulf of Mexico is Lake Pontchartrain, Lousisiana (Raney 1958). Native stripers have been reported from the Tickfaw (Raney 1952) and Tchefuncte Rivers (Pearson 1938). A steady decline of native striped bass populations was described by Davis et al. (1970), and no records documenting its presence in 1956 were found (McIlwain 1980a).

Commercial landings of native striped bass in Louisiana were minor compared to total commercial landings each year, thus no records of striped bass landings were reported. During the 1880s striped bass were often found in New Orleans fish markets (Gowanloch 1933, cited in McIlwain 1980a).

Since 1965, stocking programs have attempted to reestablish striped bass populations in coastal Louisiana streams. Sizable ATL populations now occur at the mouth of the Mississippi River, Barataria Bay, and in the Mermentau, Calcasieu, and Sabine Rivers. Mermentau River populations are from Chesapeake Bay brood stock (McIlwain 1980a).

3.2.1.5 Texas

Native (Gulf race) striped bass have not been reported from Texas waters. Through stocking, the range of ATL striped bass in Gulf of Mexico waters has been extended westward to San Antonio Bay on the central Texas coast (McIlwain 1980a). This population is most directly affected by water release from dams and impoundments upstream.

3.2.2 Distribution

3.2.2.1 Range

Gulf race striped bass - abbreviated STB-G by the U.S. Fish and Wildlife Service - historically ranged from Suwannee River, Florida to Lake Pontchartrain, Lousisiana. These native striped bass infrequently found south of the Suwannee River are probably stragglers from more northern stocks inhabiting the Apalachicola, Ochlockonee, and Choctawhatchee Rivers (Williams and Grey 1975).

3.2.2.2 Eggs

Not known. May be similar to striped bass along the Atlantic coast.

3.2.2.3 Larvae

May be similar to striped bass along the Atlantic coast.

3.2.2.4 Juveniles

Young-of-the-year STB-G have been captured in the tailrace of Jim Woodruff Dam on the Apalachicola River. Habitat and distributions are not known.

3.2.2.5 Adults

STB-G populations are endemic and riverine. Adults seldom venture into the Gulf of Mexico. Adults appear to migrate upstream to spawn in the spring. Westward movement has been observed in the Intracoastal Waterway near the Apalachicola River, Florida.

3.2.3 Reproduction

3.2.3.1 Maturity

The smallest flowing STB-G male captured in the Apalachicola River was 2.3 kg. No Atlantic race (ATL) males flowing with milt were captured. The smallest gravid STB-G female collected weighed 4.8 kg; smallest ATL female was 4.7 kg (Crateau et al. 1980).

3.2.3.2 Mating

Probably similar to Atlantic coast populations.

3.2.3.3 Fertilization

Eggs are released in open water areas of rivers where they are fertilized.

3.2.3.4 Fecundity

Not known.

3.2.4 Spawning

3.2.4.1 Season and Location

APALACHICOLA RIVER - Historically, the primary spawning ground was located on the Flint and Chattahoochee Rivers. Completion of the Jim Woodruff Dam essentially blocked anadromous runs, although Georgia Game and Fish data indicate spawning activity still occurs in the Flint River above the dam. The principle striped bass spawning ground now appears to be the tailrace area of Jim Woodruff Lock and Dam. Spawning occurs from early April to early May for Gulf race (STB-G) stripers (Crateau et al. 1980). ATL stripers may have a similar spawning season; data presented by Crateau et al. (1980) suggest mid-April to early May.

3.2.4.2 Temperature

APALACHICOLA RIVER - The first glowing STB-G male was observed at a temperature of 9.6 C, and the first STB-G gravid female was collected at 14.8 C. Staged eggs were not observed until water temperatures reached 20 C. The first spent STB-G female was captured at 20.8 C and flowing STB-G males were still captured in mid-May at 22.3 C. The first staged ATL female was collected at 20 C and gravid ATL females were collected on 7 May at 22.3 C. No ATL males flowing with milt were collected (Crateau et al. 1980).

3.2.4.3 Spawning Habitat

Probably similar to Atlantic coast populations.

3.2.4.4 Diel Spawning Patterns

No information available.

3.2.5 Life History - Eggs and Larvae

No information is yet available on the hatching, growth, hardiness, swimming ability, or tolerances of STB-G eggs and larvae to chemicals and pressure. Some of this information may soon be determined through the STB-G culture program currently being conducted by the U.S. Fish and Wildlife Service.

3.2.6 Life History - Juveniles

3.2.6.1 Nutrition and Growth

FEEDING - No information available.

GROWTH - Juvenile STB-G striped bass 45 to 75 mm TL were collected in the Apalachicola River during July and August 1959; others collected between December 1957 and May 1958 ranged from 113 to 196 mm TL (Barkaloo 1970).

METABOLISM - Not known.

3.2.6.2 Hardiness

Data is lacking on the effects of the following factors on STB-G juveniles: salinity, temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport. STB-G have been transported successfully by air and were stocked in prepared ponds at Natchitoches National Fish Hatchery in 1980 (Memorandum to Regional Director, FWS, Atlanta, Georgia from Senior Staff Spécialist-Fisheries, FWS, Jacksonville, Florida, 22 May 1980). Fry were packed in standard styrofoam shipping boxes at 100,000 per hour and arrived by small aircraft at Natchitoches about six hours after boxing. Fry survival was over 90% and 27,000 fingerlings were produced from the 50,000 fry. STB-G fry and fingerlings appear to be at least as hardy as the Moncks Corner strain (M.L. Hickman 1981, pers. comm.).

3.2.6.3 Swimming Ability

No information available.

3.2.6.4 Chemical Tolerance

No information available.

3.2.6.5 Pressure

No information available.

3.2.7 Life History - Adults

3.2.7.1 Longevity

The oldest STB-G and ATL stripers collected in the Apalachicola River were ages XIII and X, respectively (E.J. Crateau 1981, pers. comm.).

3.2.7.2 Nutrition and Growth

FEEDING - Food is abundant in the Apalachicola River. Prey items include threadfin shad, skipjack herring, Alabama shad, and American eels (Crateau et al. 1980). Seventy-five percent of the stomachs examined from 20 striped bass 496 mm to 935 mm FL contained food; threadfin shad (53.3%) and American eels (33.3%) comprised the major food items. Other prey items included Atlantic needlefish (6.6%) and unidentified fish remains. Additional data collected by sportfishing indicated that schools may feed simultaneously, gorging themselves over a short period of time (Crateau et al. 1980). In the Biloxi Bay system, adult stripers generally feed on menhaden while residing in the lower reaches and on shad while in the upper portions of the river (McIlwain 1980b).

GROWTH - The mean ratio of standard length (SL) to fork length (FL) for Apalachicola River striped bass is represented by the equation

$$FL = 1.13SL - 9.33, \quad r = 0.996.$$

Greatest growth occurs in the first year of life, averaging 180 mm (Table 3.2-1). Growth increments decreased gradually until age IX; from that age an average growth of 10 mm per year is maintained. Apalachicola River fish have a slightly higher growth rate compared to other open-water striped bass populations during their first year of life. The length-weight relationship (races combined) is

$$\mathrm{Log}_{10} W = -5.19 + 3.15\ (\mathrm{Log}_{10} L), \quad r = 0.98$$

where W is weight in grams and L is fork length in mm. The length-weight relationships calculated separately for each race are

$$\text{STB-G} \quad \mathrm{Log}_{10} W = -5.68 + 3.33\ (\mathrm{Log}_{10} L), \quad r = 0.98.$$

$$\text{ATL} \quad \mathrm{Log}_{10} W = -4.26 + 2.81\ (\mathrm{Log}_{10} L), \quad r = 0.98.$$

There is no significant difference (P>0.05) in the length-weight relationship between the two races (Crateau et al. 1980). During summer, fish in cool thermal pockets (21 C spring water) exhibited slight loss of condition, suggesting slowed by continued feeding; most fish examined in winter and spring were in excellent condition. There was no significant difference in the condition (K) factor between Atlantic

Table 3.2-1. Annual growth rates (mm) of striped bass populations in river systems along the Gulf coast.

RIVER SYSTEM	SEX	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	SOURCE(S)
Apalachicola River 1980	C[1]	180	163	135	114	104	85	58	26	13	13	12	12	9	Crateau et al. (1980)

1 Based on back calculated FL (mm) at scale annulus formation.

(ATL) and Gulf (STB-G) striped bass in the Apalachicola River. Condition factors were much higher than for Choctawhatchee River striped bass as reported by Wigfall and Barkaloo (1975), suggesting that Apalachicola River striped bass survive and thrive better than those striped bass stocked in the Choctawhatchee River (Crateau et al. 1980).

METABOLISM - No information available.

3.2.7.3 Hardiness

Data is lacking on the effects of the following factors on adult Gulf race striped bass: salinity, temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport. STB-G adults have been transported successfully from river systems to hatchery facilities, but information on transporting procedures was not detailed.

3.2.7.4 Swimming Ability

No information available.

3.2.7.5. Chemical Tolerances

No information available.

3.2.7.6 Pressure

No information available.

3.2.8 Behavior

3.2.8.1 Juvenile Migration and Local Movement

APALACHICOLA RIVER - During 1957, fishermen below Jim Woodruff Dam caught large numbers of juvenile native striped bass 45 to 75 mm TL. Similarly-sized fish were also caught from the Chipola Cutoff in July 1959 and from below the dam in August (Barkaloo 1970).

3.2.8.2 Adult Migration and Local Movement

APALACHICOLA RIVER - Two distinct migrations occur, one in the fall from mid-October to mid-November, and the second from late December through April. The fall run is closely associated with decreasing water temperatures below 22 C, which apparently causes stripers to greatly

increase their feeding patterns. The spring migration involves spawning activity and appears to be correlated with a rise in temperature (Crateau et al. 1980). Striped bass of similar size and age tagged from 1976 to 1978 exhibited no predictable movement pattern, as tagged fish moved in all directions away from the tagging site. There was no statistically significant relationship between fish size and distance traveled. Tag returns indicated a riverine population with some westward movement through the Intracoastal canal. Sixty-four percent of the striped bass were recaptured out of the area of initial tagging (over 8.1 km). During summer, fish were observed in cool 21 C oxygenated water from underwater springs or spring-fed creeks while surface temperatures rose to 31 C. Fish from these areas exhibited a slight loss of condition suggesting a slowed but continued feeding throughout the summer (Crateau et al. 1980).

CHOCTAWHATCHEE RIVER SYSTEM - Greatest striped bass abundance, as estimated by sportfishing, occurred in this Florida river system from September through December. Most striped bass (85.4%) were caught in the area of Western Bay to a point just upstream from Mitchell River Island, and only 2.1% were captured from the Island upstream to Holmes Creek. An additional 12.5% were collected in the mid-section of Choctawhatchee Bay. No other catches were reported during January through August (data presented by Morrow 1974).

BILOXI BAY - Adult stripers were recaptured in the river in which they were tagged. Stripers apparently move up and down the river within a 10 mile stretch and remain in the system for the first three years. Several larger fish (2.1 to 4.8 kg) were caught in mid-April on Front Beach in Mississippi Sound near the Gulfport Small Craft Harbor; the largest fish was heavy with green roe. None were native (STB-G) stripers (McIlwain 1980b).

3.2.8.3 Responses to Stimuli

No information available.

3.2.9 Population

3.2.9.1 Sex Ratio

APALACHICOLA RIVER - Crateau et al. (1980) reported the sex composition of striped bass collected in 1979 and 1980 by dividing them into four size classes. The following results were obtained:

Size (mm FL)	M:F
200 to 399	1:2
400 to 599	1:1.5
600 to 799	1:3.3
800 to 1000	1:2.7

Average male to female ratio was 1:2.1 (data from Crateau et al. 1980). Native and Atlantic race striped bass were not separated.

3.2.9.2 Age Composition

APALACHICOLA RIVER - In 1980, stripers (native and stocked races not separated) ranged from age class I to XIII; ages IX through XII were missing from the captured population (Table 3.2-2). Age class III (1976 year class) comprised 42.2% of the total population. The 1976 stocking of 33,600 Atlantic race striped bass from Moncks Corner, South Carolina by the State of Florida exhibited a good survival rate. Successful reproduction the same year by Gulf race stripers combined to form the dominant year class, perhaps the largest since the 1971 year class (Crateau et al. 1980). Age classes IX through XII were collected in 1981 (E.J. Crateau 1981, pers. comm.).

3.2.9.3 Size Composition

Gulf race females are larger than males (Crateau et al. 1980). Age-length data for Apalachicola River striped bass (STB-G and ATL combined) are presented in Table 3.2-3.

3.2.9.4 Abundance and Population Status

Perhaps the only remaining viable spawning population of Gulf race striped bass in Gulf of Mexico waters is located in the Apalachicola River, Florida. However, stocking programs using Atlantic race striped bass and *Morone* hybrids may have diluted the native striped bass gene pool; presently only 30% of *Morone* species fish are native (STB-G) striped bass (E.J. Crateau 1981, pers. comm.). Questionnaire responses by marine and freshwater representatives indicated that the status of native striped bass in Gulf waters is unknown (Table 3.2-4). Gulf coast striped bass remaining in these river systems are probably stragglers; of the 69 adult striped bass caught from the Alabama River and seven from the Tensaw River, only one was a Gulf

Table 3.2-2. Age composition (%) of striped bass populations in Gulf coast river systems within Region 4. M = males; F = females; C = sexes combined.

RIVER SYSTEM	SEX	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	SOURCE(S)
Apalachicola River 1980	C	6.3	14.1	42.2	10.9	6.3	3.1	4.7	10.9	-	-	-	-	1.6	Crateau et al. (1980)

Table 3.2-3. Size composition (mean fork length in mm) of striped bass populations in Gulf coast river systems within Region 4. M = males; F = females; C = sexes combined.

RIVER SYSTEM	SEX	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	SOURCES(S)
Apalachicola River 1980	C[1]	180	343	478	592	696	781	839	865	878	891	903	915	924	Crateau et al. (1980)

[1] Back calculated FL at scale annulus formation

coast race female (Memorandum to Senior Staff Specialist - Federal Aid, Atlanta, Georgia, from Lou A. Villanova, 30 December 1980). Atlantic race striped bass stocked in these systems are surviving, and some populations have become self-sustaining. Apparently, dams, channelization, and poor water quality have been important in contributing to the decline of native striped bass populations along the Gulf coast (Table 3.2-5).

3.2.9.5 Factors Affecting Reproduction and Recruitment

Demise of the Gulf race striped bass primarily has been the result of dam construction, which prohibits migration of striped bass to upstream spawning areas, and deterioration of water quality (Shell and Kelly 1967, 1968; Crateau et al. 1980; McIlwain 1980a). Present stocking practices using Atlantic race striped bass and *Morone* hybrids may have diluted the gene pool of native striped bass in the Apalachicola River and may threaten the spawning viability of the population (Crateau et al. 1980, McIlwain 1980a).

3.2.9.6 Mortality

No information available.

3.2.10 Predator-Prey Relationships

No information available.

3.2.11 Diseases

No information available.

3.2.12 Exploitation

3.2.12.1 Gear

Gill nets were used as commercial fishing gear for exploiting native striped bass populations throughout the Gulf during the late 1800s and up until the early 1960s; presently, exploitation of native striped bass is only by sport fishermen using rod and reel (McIlwain 1980a). Data collected by creel census, electroschocking, and mark-recapture indicates seven to eight percent of all Apalachicola stripers are being caught (E.J. Crateau 1981, pers. comm.).

Table 3.2-4. Status of striped bass (Gulf race), *Morone saxatilis*, in river systems within Region 4 based on questionnaire responses to question VI-2. S = response from marine representative; F = response from freshwater representative.

RIVER SYSTEM	STATUS
FLORIDA (Gulf coast)	
Hillsborough R.	Probably never present (S)
Suwannee R.	Probably never present (S)
Apalachicola R.	Threatened (S), Stable (F)
Ocklockonee R.	
Escambia R.	
GEORGIA	
Chattahoochee R.	Increasing (F)
Flint R.	Increasing (F)
ALABAMA	
Alabama R.	Declining (S), No longer present (F)
Tombigbee R.	Declining (S)
Perdido R.	Not known (S)
Bon Secour R.	Not known (S)
Fish R.	Not known (S)
Magnolia R.	Not known (S)
Dog R.	Not known (S)
Fowl R.	Not known (S)
Tennessee R.	Probably never present (F)
Chattahoochee R.	
Coosa R.	No longer present (F)
Tallapoosa R.	No longer present (F)
MISSISSIPPI	
Pascagoula R.	Not known
Tchouticabouffa R.	Not known
Biloxi R.	Not known
Wolf R.	Not known
Jourdan R.	Not known
Pearl R.	Not known
LOUISIANA	
Pearl R.	Not known
Bayou LaCombe	Not known
Tchefuncte R.	Not known
Tangipahoa R.	Not known
Tickfaw R.	Not known

Table 3.2-4. Striped bass, Gulf race (cont'd.).

RIVER SYSTEM	STATUS
LOUISIANA (cont'd.).	
Amite R.	Not known
Mississippi R.	Not known
Atchafalaya R.	Probably never present
Vermillion R.	Probably never present
Mermentau R.	Probably never present
Calcasieu R.	Probably never present
Sabine R.	Probably never present

Table 3.2-5. Factors possibly important or very important to the decline of certain populations of striped bass (Gulf race), *Morone saxatilis*, within Region 4 based on questionnaire responses to question I. S = response from marine representative; F = response from freshwater representative; C = response from other agencies.

FLORIDA

- Channelization (F)
- Dredge and fill projects (F)
- Bulkheading (F)
- Location of industrial discharges (S)
- Chemical pollution (F)

ALABAMA

- Bulkheading (F)
- Dams and impoundments (FS)
- Location of industrial discharges (FS)
- Road construction (S)
- Low oxygen levels (S)
- Sewerage outfalls (S)
- Inadequate fishway facilities (FS)
- Inadequate control of water release from dams (F)
- Reduction in spawning habitat (F)
- Reduction in nursery areas (F)
- Poor food availability (S)
- Poor water quality (FS)

GEORGIA

- Dams and impoundments (F)
- Inadequate fishway facilities (F)

MISSISSIPPI

- Poor water quality

LOUISIANA

- Channelization
- Dams and impoundments

TEXAS

- Dams and impoundments
- Inadequate control of water release

3.2.12.2 Fishing Areas

Barkaloo (1961) reported greatest fishing success for striped bass at the Jim Woodruff Dam tailrace, mouths of creeks, Intracoastal Waterway, and the Chipola River at the mouth of Dead Lakes.

3.2.12.3 Fishing Seasons

Greatest fishing success in the Apalachicola and Choctawhatchee Rivers is in the fall during increased striped bass feeding activity and in the spring during spawning activity (Morrow 1974, Crateau et al. 1980). Fishing for stripers in the Intracoastal Waterway is good only during winter months (Barkaloo 1961).

3.2.12.4 Effort

No catch-effort statistics were available for only native (STB-G) striped bass. Creel census data from Florida and the FWS indicated 2,105 man-hours of effort produced 169 stripers (0.8 fish hr^{-1}) in the Apalachicola River during the period 26 January 1979 through May 1979 (E.J. Crateau 1981, pers. comm.). Fishing success for stripers in Choctawhatchee River during 1974 was .002 fish hr^{-1} in September, 0.0293 fish hr^{-1} in October, and 0.0455 fish hr^{-1} in November, and dropped to 0.0045 fish hr^{-1} in December. The average sport fishing harvest per hour was best with dead (0.0331 fish hr^{-1}) or live (0.0296) shrimp. Success rate by gear type was trolling, 0.0268; bank fishing, 0.0102; drift netting in bay, 0.0183; and drift netting in the river, 0.0097. Greatest harvest (85.4%) occurred in western Choctawhatchee Bay and river mouth, with an additional 12.5% captured in mid-bay. Only 2.1% were taken in the river upstream to Holmes Creek (data from Morrow 1974).

3.2.13 Protection and Management

3.2.13.1 Gulf Coast Race Striped Bass Management Plan

Following is the management plan formulated for Gulf race striped bass as approved by the U.S. Fish and Wildlife Service, Region 4, on 5 February 1981.

GOAL - "Restore the Gulf coast race striped bass (STB-G) to biologically suitable areas of its former range, consistant with State management programs.

"The Gulf coast race of Morone saxatilis has been reduced essentially to a single small subpopulation. Continued reduction of habitat or degradation of water quality could make survival of this race questionable. The Gulf race striped bass population was restricted to the Apalachicola River system, with relics reported in other rivers. A U.S. Fish and Wildlife survey in 1979 verified the presence of Gulf race striped bass in the Apalachicola River system. After verification of the presence of Gulf race stripers in the Apalachicola River, the Panama City Office of Fishery Assistance carried out a survey to determine their relative abundance in comparison to Atlantic strains and captured STB-G for future broodstock to provide a reservoir of the race for protection and stocking efforts. Adult Gulf race stripers were transported to the Welaka National Fish Hatchery, Florida, during March and April 1980 for future spawning activities. On 2 May 1980, one adult female was successfully spawned and approximately 400,000 healthy fry were obtained. This was accomplished after extreme dedication of the Office of Fishery Assistance and Welaka National Fish Hatchery personnel and, to our knowledge, was the first successful effort to capture and spawn the Gulf race under hatchery conditions.

Objectives and Action

"To accomplish the stated goal, program objectives are outlined:

"OBJECTIVE 1: Establish a Gulf Coast Race Striped Bass Restoration Advisory Group of U.S. Fish and Wildlife personnel:

a. The group was established on 22 July 1980.

b. The advisory group was charged with responsibility of preparing this plan in draft form by 15 November 1980.

c. The group will coordinate Service efforts and work closely with the Gulf States that have an interest in reestablishing STB-G populations. The Service will work closely with the States and in no way usurp State management prerogatives.

"OBJECTIVE 2: Determine the extent of capture and spawning activities for 1981.

a. Spawning potential from the Apalachicola River, Florida, based upon 1980 experience will be set at three females. The number of eggs cannot be accurately assessed until the females are captured. A conservative estimate is 1.5 to 2.0 million eggs, 750,000 fry.

b. Spawning potential from other river systems does not exist at this time. Occasionally a remnant STB-G is reported from another system, but for all practical purposes we cannot plan on collecting broodstock from any other source than the Apalachicola River.

"OBJECTIVE 3: Reinforce the 1980 broodstock program to assure future STB-G for restoration programs.

a. Establish a second-year class at Mammoth Spring, Natchitoches, and Welaka National Fish Hatcheries. If space and fingerlings are available, a second-year class can be established at Millen National Fish Hatchery. Estimated number of fingerlings for the 1981 broodstock program is set at 10,000 (30,000 fry).

"OBJECTIVE 4: Continue stocking efforts for restoration of the Gulf race throughout the Gulf of Mexico based on State concurrence.

"OBJECTIVE 5: Promote research into the causes of decline of the Gulf coast race of striped bass and factors limiting its survival and/or abundance in Gulf streams.

"OBJECTIVE 6: Monitor the status of the Gulf coast race striped bass. The Service will be continuously monitoring the status of the Gulf coast race striped bass. As new biological data become available on its distribution, population status, threats to its survival and success of restoration efforts, involved State and Federal agencies will be kept informed of the progress of this monitoring and will be given opportunities to contribute data and express their views relevant to the species' status.

"OBJECTIVE 7: Mark and Recovery Program. A satisfactory marking is essential to evaluate successes of management efforts. However, difficulty has been encountered in successfully marking striped bass. A literature search has been conducted. There are several techniques presently being developed, but none are perfected or practical at this time.

"The Welaka National Fish Hatchery, Florida, was able to bone mark a group of 13,000 STB-G by using oxytetracycline (Terramycin). This pioneering achievement was performed on six-inch fingerlings. Examination of fish at a bone marking workshop at Welaka in late November 1980 gave rise to hopes that a permanent bone mark may be possible for Phase I (1½") fingerlings. It is believed previous efforts to mark fish in this manner failed because workers were unfamiliar with the identifying technique and equipment necessary to observe the flourescing green mark. Bone-marked fish will be identified by conventional fish sampling techniques and by creel census. This type of mark only partially alleviates the problem as bones containing the mark will be available only from dead or sacrificed fish.

"A method being developed at the Marion, Alabama, laboratory is the use of magnetic micro-tags. The gun used to apply the tags has not been perfected, and fish either are being literally blown apart by air pressure or the tags are clogging the gun. A great deal of additional work needs to be done before this method can be employed. At the present time the only methods that can be used are the external flag or spaghetti-type tags. This is extremely labor-intensive, expensive, and results in a high rate of fish mortality and unproven tag retention. The advantage of this type of marking is that it is readily recognized by the fishermen who give us information on returns of stocked fish. During the 1980 stocking season, 1,600 six-inch STB-G were tagged by the Gulf coast research laboratory prior to being stocked in the Pascagoula River. The laboratory will provide tag-return data to the Service in a cooperative effort to evaluate stocking success.

"SUMMARY OF 1981 STOCKING PROGRAM - Broodstock now being held at the National Fish Hatcheries will not spawn until 1985, so the 1981 stocking program is entirely dependent upon the success of the 1981 Apalachicola River spawning success (Table 3.2-7). (1980 STOCKING PROGRAM: Table 3.2-6).

"CLOSING STATEMENT - This management plan will be modified at least once each year. We are dealing with a race of fish which has been spawned and cultured for the first time. There are many unknowns regarding spawning potential for successful fry and fingerling rearing. The Fishery Resources people of the U.S. Fish and Wildlife Service are once again setting the pace in culturing a race that has never been cultured before and initiating management plans for a race not previously managed. Our basic goal will be obtained when we have established a self-sustaining fisheries population providing 0.25 fish per angler hour of effort in two native Gulf coast river systems."

Table 3.2-6. 1980 Production and distribution summary, Gulf coast race striped bass.

HATCHERY	FRY	PRODUCTION (Size)	DISTRIBUTION	NUMBER (Size)	MONTH
Welaka National Fish Hatchery, Florida[1]		50,000 (fry)	Natchitoches NFH, LA	50,000 (fry)	May
		172,000 (2-3")	Natchitoches NFH, LA	20,000 (2-3")	June
			Flint River - Bainbridge, GA	40,000 (2-3")	June
			Lake Seminole, GA Spring Creek	60,800 (2-3")	June
			SE. Fish Culture Lab Marion, AL	2,000 (2-3")	June
			Co-op Fish Unit, Auburn University	2,000 (2-3")	June
		13,000 (6-8")	Apalachicola River, FL	12,500 (6-8")	November
			Welaka NFH - future brood	500 (6-8")	November
Natchitoches National Fish Hatchery, Louisiana	50,000	4,000 (2-6")	Mammoth Spring NFH, AR		July
		11,000 (6-8")	Pascagoula River, MS Bluff Creek	11,000	November
	20,000[2]	2,000 (6-8")	Pascagoula River, MS Bluff Creek	1,500	November
			Natchitoches NFH - future brood	500	November

Table 3.2-6. 1980 Production and distribution summary (cont'd.).

HATCHERY	FRY	PRODUCTION (Size)	DISTRIBUTION	NUMBER (Size)	MONTH
Mammoth Springs National Fish Hatchery, Arkansas	4,000	3,100 (6-8")	Sabine NWR, LA	100[3]	November
		500 (6-8")	Mammoth Spring NFH, future brood	500	November

[1] 1,250,000 eggs were taken from a single female captured on the Apalachicola River, Florida, resulting in 400,000 fingerlings.

[2] Shipping mortality was 12,000

[3] Mortality enroute was 3,000

Table 3.2-7. 1981 Gulf race striped bass stocking program by the U.S. Fish and Wildlife Service. Stocking is conducted only with written approval from the State involved.

Water and State	Number and Size	Priority
Broodstock & Research	35,000 various	1
Apalachicola River system, FL	20,000 six-inch (marked)	2
Pascagoula River, MS	15,000 six-inch (marked)	3
Apalachicola River system, FL	100,000 fingerlings	4
Apalachicola River system, GA	100,000 fingerlings	5
Pascagoula River, MS	300,000 fingerlings	6
Apalachicola River system, GA	100,000 fingerlings	7
Pascagoula River, MS	300,000 fingerlings	8

Before additional river systems are stocked, further evaluation will be made on the above systems to assure maximum practical stocking efforts have been attained.

The following river systems and stocking numbers are listed in a rough priority order, but before fish are stocked, additional studies will be made to determine potential success for reintroduction.

Pearl River, MS	10,000 six - inch
Escambia River, FL	100,000 fingerlings
Perdido, Blackwater, and Styx Rivers, AL	20,000 fingerlings
Pearl River, MS	200,000 fingerlings
Choctawhatchee River, FL	100,000 fingerlings
Yellow River, FL	50,000 fingerlings
Blackwater River, FL	50,000 fingerlings

3.2.13.2 Florida

Crateau et al. (1980) reviewed the problems associated with collecting data on STB-G in the Apalachicola River, Florida. The best method was to monitor the catch during fishing tournaments held in November 1979 and March 1980. This also gave the U.S. Fish and Wildlife Service biologists an opportunity to address the only organized group of striped bass fishermen on the Apalachicola River to inform them of the study and to solicit their cooperation. Gill netting in the tailwaters of Jim Woodruff Dam December through March was extremely difficult and stressed potential broodstock beyond recovery. Hoop nets fished in the same area were unsuccessful. Electroshocker proved to be the best method for capturing striped bass in healthy condition suitable for hatchery purposes (Crateau et al. 1980).

A U.S. Fish and Wildlife Service stocking program, using South Carolina stock, was begun in the Choctawhatchee River system in June 1968. Initial stocking was 118,000 fingerlings and 14,000 advanced fingerlings, all introduced into estuarine areas. Returns from this 1968 year class indicated almost no survival of fingerlings but good survival of advanced fingerlings. In 1969, 215,000 fingerlings and 4,000 advanced fingerlings were stocked in Choctawhatchee Bay with results similar to the previous year. Stocking procedures were changed following the 1970 season; all fingerlings were released in the river of freshwater tributaries to the bay, while advanced fingerlings were released in the upper bay and river delta. By 1974, 3,682,000 striped bass of South Carolina stock had been planted in the Choctawhatchee River and Bay representing approximately 26.8 fish per acre (Morrow 1974). A spawning run was observed in the system in 1975 (Smith 1975).

3.2.13.3 Alabama

In 1967, efforts were begun to reestablish a self-sustaining striped bass population in coastal waters. The Alabama Marine Resources Division (AMRD) subcontracted with Auburn University under Public Law 89-304 to produce striped bass fingerlings for release into Alabama estuaries. The AMRD was limited to cage culture at the Dauphin Island Marine Laboratory from 1969 to 1973 and only 40,000 fingerlings were released. The vast size of Alabama estuaries (160,872 ha of open water, 494 km of streams (Crance 1971) necessitated a stocking rate of two to three fish per hectare per

year in order to reestablish the population. To meet this demand, the Claude Peteet Mariculture Center at Gulf Shores, Alabama, was constructed specifically as a brackish water anadromous fish hatchery. In 1975, this facility allowed stocking rates to exceed a release of two to three striped bass per hectare in Alabama coastal waters (Powell undated).

3.2.13.4 Mississippi

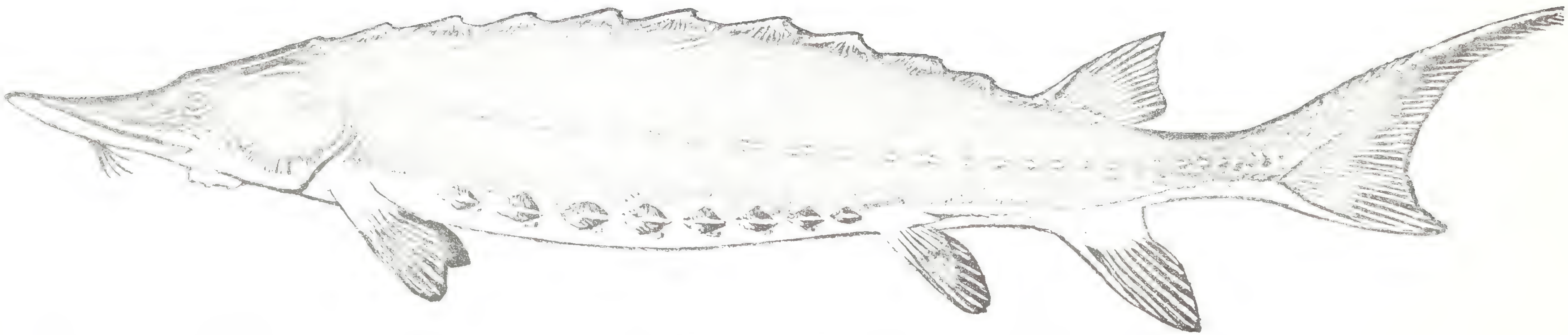
Striped bass (South Carolina strain) have been stocked in Mississippi coastal streams since 1969. No evidence of eggs or larvae have been discovered in Mississippi river systems, suggesting that these populations are not self-sustaining (McIlwain 1980a). During a three-year study (1977 to 1979), a total of 1,200,527 striped bass fingerlings of South Carolina origin were reared and stocked into Biloxi Bay and 35,948 sea-run striped bass fingerlings were planted into St. Louis Bay. Striped bass stocked in Mississippi coastal streams are surviving, growing, maturing, and being caught in greater numbers each successive year (McIlwain 1980b).

3.2.13.5 Louisiana

No information available.

3.2.13.6 Texas

No information available.



ATLANTIC STURGEON (_Acipenser_ _oxyrhynchus_ _oxyrhynchus_)

3.3 Atlantic Sturgeon (*Acipenser oxyrhynchus oxyrhynchus*)

3.3.1 Historical Significance

The Atlantic sturgeon is a nominate subspecies which ranges from the Atlantic coast of Labrador and Gulf of St. Lawrence to eastern Florida. It is represented in the Gulf of Mexico, Bermuda, and French Guiana by the Gulf coast sturgeon, *Acipenser oxyrhynchus desotoi* Vladykov (Jones et al. 1978). Information regarding the Gulf coast sturgeon is presented in Section 3.4.

The Atlantic sturgeon is also commonly known as sea sturgeon, common sturgeon, sharp-nosed sturgeon, and esturgeon noir. This species has long been utilized and exploited along the Atlantic coast of the United States. Aboriginal Americans made use of sturgeon as early as 2198 B.C. (Ritchie 1969). Overexploitation, deterioration of water quality, and habitat reduction through damming of rivers have been important in contributing to the decline of a once important industry.

3.3.1.1 North Carolina

The Atlantic sturgeon and shortnose sturgeon (*Acipenser brevirostrum*) have been commercially important in the North Carolina finfish fishery since the 1800s. In 1880, sturgeon contributed at least 436,900 pounds valued at $18,894 to the fishery. Specimens 12 feet long weighing up to 500 pounds were common at the turn of the century but seldom exceed 8.5 feet and 380 pounds today. Gill nets and seines were used in the late 1800s. The present (1976) sturgeon fishery in Carteret County relies mainly on otter trawl and a single gill net (Schwartz and Link 1976).

The drastic decline in populations of Atlantic sturgeon and shortnose sturgeon was probably influenced by changes in estuarine habitats. Since 1973, shortnose sturgeon has been listed as an endangered species and may have been extirpated in North Carolina waters since 1905 (Street 1980, pers. comm.). Commercial landing statistics presented in Section 3.3.12.4 may include shortnose sturgeon up to year 1973.

3.3.1.2 South Carolina

The sturgeon fishery in South Carolina is limited to those streams rising sufficiently far inland to have a strong flow of freshwater before entering the estuarine areas near the Atlantic Ocean. Some small streams (Stono River, Awendaw Creek, May River, and Ashley River) have

historically provided sturgeon habitat but seem to no longer attract this species. Fisheries are therefore limited to the Waccamaw-Pee Dee, Santee-Cooper, Edisto, and Ashepoo-Combahee river systems (Leland 1968).

Sturgeon have contributed importantly to finfish landings in South Carolina. Sturgeon landings peaked in 1897 at 411,000 pounds of meat and 70,000 pounds of caviar. After this time, landings dropped sharply and have never recovered (Laurie 1979). Presently, over 90% of the commercial landings in South Carolina occur in the Winyah Bay system (Smith 1979). In 1978, only 18 fishermen purchased sturgeon net licenses and landed 70,500 pounds of sturgeon meat worth $28,200 (Smith 1979). The average size landed was slightly more than six feet long and 124 pounds (Laurie 1979). Total participation in the sturgeon fishery statewide was 25 to 30 fishermen in 1978 and 30 to 35 fishermen in 1979 (Smith 1979). Sturgeon weighing more than 900 pounds were caught as late as 1904; apparently fish this large do not exist in South Carolina waters today (Leland 1968).

Although the sturgeon fishery is not large, the demand for caviar and smoked sturgeon is high, resulting in a good price to fishermen. Sturgeon was not regarded as a food fish in South Carolina to any great extent until after the Civil War; presently, most meat is shipped fresh to New York and Miami to be smoked. Caviar is prepared and sold locally, bringing $25 to $30 per pound (Leland 1968). A dealer in South Carolina reported 1967 to be the worst year in the history of the sturgeon fishery; some shipments of meat from Winyah Bay were rejected by New York buyers due to the availability of filletted sturgeon from Iran (Leland 1968). Iranian fishermen were able to catch, prepare, freeze, and ship sturgeon meat to New York cheaper than could the dealer from Georgetown, South Carolina (Leland 1968). Total value of the sturgeon fishery (meat and caviar) was $50,059 in 1978 and $73,129 in 1979 (Smith 1979).

Rivers in South Carolina were deep and clear-running until 1825 when agricultural development began in upland areas. Decline in the sturgeon population may have been due to loss of habitat from dams, pollution, and overfishing (Laurie 1979).

3.3.1.3 Georgia

No information available.

3.3.1.4 Florida

Atlantic sturgeon are relatively rare on the Atlantic side of the Florida peninsula. A small commercial fishery employing one to two men is operating in the St. Marys River, but in the St. Johns River sturgeon are rarely observed. Occasionally, shad fishermen catch sturgeon in gill nets set at the St. Johns River mouth, and shrimp trawlers rarely catch sturgeon offshore. Sturgeon are more common on the Gulf coast of Florida, and support gill net fisheries in several rivers. However, this sturgeon is subspecies *Acipenser o. desotoi* (Williams and Grey 1975).

3.3.2 Distribution

3.3.2.1 Range

Atlantic sturgeon range from Hamilton River Inlet, Labrador (Backus 1950), to the St. Johns River, Florida (McLane 1955, Williams and Grey 1975). No significant populations of Atlantic sturgeon exist south of the St. Marys River (Williams and Grey 1975).

3.3.2.2 Eggs

Sturgeon eggs are adhesive and demersal, occasionally occurring in ribbonlike clusters. Eggs adhere to vegetation and stones, and hatch in approximately seven days. Eggs have been collected in brackish or freshwater over hard bottoms of clay, gravel, or shell in shallow running water or in depths up to five fathoms (Vladykov and Greeley 1963).

3.3.2.3 Larvae

Young Atlantic sturgeon are rarely seen; therefore, little is known of their distribution.

3.3.2.4 Juveniles

Young Atlantic sturgeon may spend one to three years in freshwater natal streams before emigrating to sea (Dees 1961, Scott and Crossman 1973). Juveniles are benthic and eat a wide variety of bottom-associated plant and animal materials.

3.3.2.5 Adults

Little is known concerning distributions of sturgeon populations offshore or during spawning migrations. In

waters offshore North Carolina, adults were mostly collected in waters less than 15 m deep (Holland and Yelverton 1973). Adults can migrate long distances in relatively short periods. Population distributions during spawning migration depend on sex and direction of movement within the river (immigration or emigration) (Huff 1975). During mid-summer months, sturgeon frequent areas of deep holes in South Carolina rivers (Leland 1968).

3.3.3 Reproduction

3.3.3.1 Maturity

St. Lawrence River populations reach sexual maturity at ages 22 to 24 for males and 27 to 28 for females (Scott and Crossman 1973). Hudson River Atlantic sturgeon age VIII and younger were all immature (Greeley 1937).

3.3.3.2 Mating

Spawning behavior for Atlantic sturgeon has not been reported in the literature; mating is probably conducted by random pairing (Murawski and Pacheco 1977). Generally, sturgeon species roll, splash, and leap out of the water during spawning. The female helps force the grayish or blackish eggs from her ovaries by rubbing her belly on rocks or hard objects (Dees 1961).

3.3.3.3 Fertilization

Eggs are released in open waters of rivers where they are fertilized.

3.3.3.4 Fecundity

Female Atlantic sturgeon in the Delaware River contained between 800,000 and 2,400,000 eggs (Ryder 1890). North Carolina females may contain between 1,000,000 and 2,500,000 eggs (Smith 1907).

3.3.4 Spawning

3.3.4.1 Season and Location

Some female sturgeon spawn once each year (Scott and Crossman 1973). However, some fully mature females with immature ovaries are found participating in the spring spawning migration, indicating that some females may spawn only once every two or three years (Vladykov and Greeley 1963).

CAPE FEAR RIVER ESTUARY - A small spawning population of Atlantic sturgeon may exist in this system. Two sturgeon of the 45.8 kg class were captured in February and March 1976 and immature sturgeon were collected in the Northeast Cape Fear River in 1975 (Sholar 1977b).

WINYAH BAY SYSTEM - Spawning runs occur every spring in this system (Smith 1979). Eggs were observed attached to the edge of a sand bar at low tide in the Pee Dee River near Hemingway (Leland 1968). Commercial fishermen believe spawning occurs after 15 May and not later than mid-July or 1 August (Leland 1968).

ST. MARYS RIVER - Spawning begins in February (Vladykov and Greeley 1963).

ST JOHNS RIVER - It is highly improbable that Atlantic sturgeon spawn in the St. Johns River system. The only specimen captured in eight years (1946 to 1955) was found in Lake Crescent, Flagler County, on 1 April 1949 (McLane 1955).

3.3.4.2 Temperature

No information available.

3.3.4.3 Spawning Habitat

Atlantic sturgeon deposit eggs in or near fairly deep sections of rivers that are adjacent to sandbars, rock outcroppings, or areas that have gravel, rock, roots, and other rough-surfaced items to which the eggs may attach (Leland 1968).

3.3.4.4 Diel Spawning Patterns

No information available.

3.3.5 Life History - Eggs and Larvae

3.3.5.1 Hatching and Growth

The incubation period for Atlantic sturgeon eggs ranges from 94 hours at 20 C to 168 hours at 17.8 C (Murawski and Pacheco 1977). A study by Smith et al. (1980) determined that hatching began at 121 hours, peaked after 126 hours, and was completed by 140 hours with incubation temperature approximately 18 C (16 to 19 C), 10 mg l^{-1} dissolved oxygen, and pH 7.0.

GROWTH - Sac fry average 7.1 mm TL after hatching. By day 11 the yolk-sac is fully absorbed. Within the first two weeks fry approximately double their hatching length and exhibit a 4.8-fold increase in weight. By day 131 the average size is 11.5 cm and 4.64 g (Smith et al. 1980). Sytina (1975) examined several sturgeon species for divergence in the development of sensory organs (olfaction, vision, and statoacoustics). Results showed that divergence occurred in the earliest stages of ontongeny and was specified by the morpho-ecological peculiarities of the species based on species differences in growth rates and differentiation. The acceleration or slowing of receptor organ development was determined by its function for orientation at a given stage of ontogeny.

FEEDING - No information available.

METABOLISM - No information available.

3.3.5.2 Hardiness

Little is known concerning the hardiness of Atlantic sturgeon eggs and larvae as related to the following variables: salinity, temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport.

3.3.5.3 Swimming Ability

Smith et al. (1980) reported sac fry behavior in aquaria. During the first 10 days, sac fry were active and frequently swam from surface to bottom of the holding tanks, and also gathered in the corners of the tank. After day 10, the young sturgeon exhibited a more benthic behavior. After several weeks, no further gregarious behavior was observed.

3.3.5.4 Chemical Tolerances

No information available.

3.3.5.5 Pressure

No information available.

3.3.6 Life History - Juveniles

3.3.6.1 Nutrition and Growth

FEEDING - Young sturgeon in freshwater eat a wide variety of bottom-dwelling plant and animal materials. Juveniles root on the bottom with their snouts and suck in material through projected mouths. Sludgeworms (Limnodrilus),

chironomid larvae, mayfly larvae, isopods, amphipods, and small bivalve molluscs are prey items (Scott and Crossman 1973).

GROWTH - Atlantic sturgeon retain juvenile characteristics up to 122 cm FL (Murawski and Pacheco 1977). Immature sturgeon were captured emigrating from the Cape Fear River in 1975; sizes ranged from 340 to 774 mm FL. One immature sturgeon caught in the Cape Fear in Mallory Bay during September 1979 was 605 mm FL (Fischer 1980). Juveniles ranging in size from 70.6 to 84.7 cm FL (2.2 to 4.0 kg) were tagged and released in the St. Lawrence River. Recaptured juveniles yielded estimated growth of 6.3 to 14.4% in length and 28.8 to 47.0% in weight (Scott and Crossman 1973).

Experiments by Mailvan and Alekperov (1976) demonstrated that the young of some sturgeon species grow as well under hatchery conditions as in the sea for any stage of development. Linear measurements and weights are similar, and histologic patterns of gonads in reared and wild fish of the same age were similar. It was not determined if sturgeons can reach sexual maturity (12 to 15 years) in hatcheries.

METABOLISM - No information available.

3.3.6.2 Hardiness

Little is known concerning the effects of the following variables on juvenile Atlantic sturgeon: salinity, temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport.

3.3.6.3 Swimming Ability

No information available.

3.3.6.4 Chemical Tolerances

No information available.

3.3.6.5 Pressure

No information available.

3.3.7 Life History - Adults

3.3.7.1 Longevity

Little information is available on the average life expectancy of Atlantic sturgeon. Generally, sturgeon are long-lived and some species have individuals estimated to be over 100 years old (Dees 1961).

3.3.7.2 Nutrition and Growth

FEEDING - No feeding occurs during migration and spawning, but adults do feed in freshwater after spawning is completed. In the ocean, larger sturgeon eat molluscs, polychaete worms, gastropods, shrimps, amphipods, isopods, and small fishes, especially the sand lance *Ammodytes* (Scott and Crossman 1973).

GROWTH - No information available.

METABOLISM - Examination of European sturgeons revealed a change in blood cations between freshwater and saltwater, with lowest cation concentration in sturgeons held in hatcheries for extended periods (Natochin et al. 1975). Despite the sturgeon's marine origin, Atlantic sturgeon fatty acids are similar to those of a special class of fish that characteristically have fats with a composition resembling freshwater fish fats (Ackman et al. 1975).

3.3.7.3 Hardiness

Information is lacking concerning the effects of the following variables on adult Atlantic sturgeon: salinity, temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport.

SALINITY - The upstream limit for Atlantic sturgeon in the St. Johns River, Florida, is from Palatka upstream to and including Big Lake George; salinities range from 200 to 400 ppm in this area (McLane 1955).

3.3.7.4 Swimming Ability

No information available.

3.3.7.5 Chemical Tolerances

Pollution apparently plays a major role in habitat abandonment by Atlantic sturgeon. The Sampit River at Georgetown, South Carolina, had heavy industrial pollution (sulphate paper mill) for 30 years, and

sturgeon disappeared from the river shortly after the pollution began entering the river. Sturgeon also disappeared from the Lynches River (Johnsonville to the confluence with the Great Pee Dee River) after a wool scouring plant began dumping wastes in 1957. Pollution controls were imposed on the plant but sturgeon were still not present in 1957 (Leland 1968).

3.3.7.6 Pressure

Sturgeon are usually dead when removed from South Carolina trawl nets, having succumbed to heavy pressures and extended dragging time (Leland 1968).

3.3.8 Behavior

3.3.8.1 Juvenile Migration and Local Movement

Juvenile Atlantic sturgeon rarely are collected with enough frequency in river systems to enable formulation of hypotheses concerning their distribution and local movements. The fact that small sturgeon are inshore long before the larger ones in the spring suggests that smaller sturgeon remain near natal rivers until mature enough to migrate seaward (Leland 1968).

OFFSHORE NORTH CAROLINA - Most Atlantic sturgeon tagged by Holland and Yelverton (1973) were small, and few returns were expected from inland areas during their study. Most were recaptured near inlets. Sturgeon moved south along the North Carolina coast from November through January, then north along the coast during late winter and early spring. One sturgeon weighing 9.5 kg traveled 401 miles from North Carolina to Long Island in 65 days at a rate of 6.2 miles per day. There was no correlation between fish size, days out, or distance traveled (Holland and Yelverton 1973).

NEUSE RIVER - Information is very limited regarding the sturgeon population in the Neuse River. A small juvenile was captured in February 1978 by gill net in the middle Neuse River. Five juveniles were tagged and none were recaptured (Hawkins 1979). Seven small sturgeon were captured in the Neuse and Trent Rivers near New Bern in January and February 1977 (Marshall 1977).

CAPE FEAR RIVER ESTUARY - Three immature Atlantic sturgeon probably moving downstream were captured at River Km 8 above Ness Creek in September and October 1975; this may indicate a possible nursery area (Sholar 1977b). An immature sturgeon was captured in Mallory Bay below the city of Wilmington in September 1979 (Fischer 1980). Differences in spatial distribution

of juveniles within the lower estuary were reported by Huish and Geaghan (1979). From June 1975 to December 1976, 34.5% of all juvenile sturgeon collected by trawl and gill net were captured from the east side of the river, 36% in several areas within the lower reaches of Walden Creek, 26% from the water intake canal of the Brunswick Steam Electric Plant, and 3.5% within Walden Creek proper (Huish and Geaghan 1979).

SANTEE RIVER - Shad fishermen report catching large numbers of small sturgeon during the early season (Leland 1968).

EDISTO RIVER - A juvenile, 51 cm TL, originally tagged in the Edisto River in June 1978 was recaptured in May 1979 in Pamlico Sound, North Carolina. Growth was approximately 25.2 cm and it had traveled 370 miles in less than a year (Smith 1979).

WINYAH BAY - An immature sturgeon, 38 cm TL, which was tagged 12 March 1979 in Winyah Bay, was recaptured 28 March in the South Santee River after traveling an estimated 32 miles in 16 days (Smith 1979).

GEORGIA - No information available.

FLORIDA - No information was available on the local habitats, migration patterns, and distributions of immature Atlantic sturgeon in Atlantic coast rivers.

ST. LAWRENCE RIVER - Young sturgeon progressively move toward the ocean. At different points they can still move upstream or downstream in search of food or proper conditions of water temperature and tide until the time they enter the ocean. Tagged young exhibited extensive migration; one migrated 900 miles, and 17 migrated more than 100 miles (Magnin and Beaudieu 1960).

3.3.8.2 Adult Migration and Local Movement

OFFSHORE NORTH CAROLINA - Recaptures of adult tagged sturgeon indicate a seasonal migration southward offshore North Carolina and Virginia, and a northward migration after January (Holland and Yelverton 1973). From November through February 1968-69 most sturgeon were collected north of Cape Hatteras in a fairly-even distribution along the beach in waters 0 to 10 fathoms deep. From 1969 to 1971, most were caught between Cape Lookout and the North Carolina border (Holland and Yelverton 1973). During the 11 April to 28 May 1977 most sturgeon were captured in the vicinity of Wimble Shoals in mid-depth water (20.1 to 36.6 m) (Loesch et

al. 1977). Only five sturgeon were collected offshore North Carolina in 1978, all during February within 1.6 km of the beach in waters 7.2 to 12.6 m deep. Bottom temperatures were as low as 0.4 C inshore at that time (Johnson et al. 1978). A tagged female full of roe and weighing 101.3 kg was recaptured three miles offshore Cape May, New Jersey, after 26 days at liberty; distance traveled was 190 miles in a northerly direction averaging 7.3 miles per day (Loesch et al. 1977).

ALBEMARLE SOUND - Cumulative catches of sturgeon were greatest during October-November 1976; April-May and August 1977 (Loesch et al. 1977); November 1977; and April and September 1978 (Johnson et al. 1978).

WHITE OAK RIVER - Five adults were captured in April 1975 in the lower part of the river (Sholar 1975).

CAPE FEAR ESTUARY - Two adults of the 45 kg class were captured in the Northeast Cape Fear River in February and March 1976 (Sholar 1977b). Two adults, 540 mm and 720 mm FL, were caught in the Cape Fear River below Mott Creek in May 1979 (Fischer 1980). These data suggested a very small spawning population of Atlantic sturgeon was present in the river system at that period.

SOUTH CAROLINA - Large sturgeon appear near river deltas and begin moving inshore when water temperatures begin to rise rapidly in February and March. Mill dams and water supply dams on the Pee Dee, Wateree, Congaree, and Savannah Rivers have effectively blocked fish passage since the 1870s and sturgeon have been limited to the lowland sections of these rivers. Other small streams, including the Stono, May, and Ashley Rivers, and Awendaw Creek, historically contained sturgeon habitat but no longer contain sturgeon populations. Upstream migration has also been blocked by increased turbidity from agricultural development near headwaters since 1825 and development of water power mills on Fall Line rapids. In all of the rivers frequented by sturgeon there are areas with pools considerably deeper than the rest of the river. These areas are now sturgeon habitat and are frequented particularly in very warm weather or when drought causes low water levels. Several pools are 15 to 21 m deep (Leland 1968).

COOPER RIVER - Sturgeon seem to prefer swift and deepwater areas. They are often observed during May, June, July, and August leaping and rolling at the waters surface. Those seen rolling are generally in pairs, but leapers are always singles. Fishermen in this area generally set their nets in late afternoon and inspect them the following morning (Leland 1968).

SANTEE RIVER - Diversion of water flow from the Santee River 50 miles upstream to the headwaters of the Cooper River in 1942 practically ended the sturgeon fishery in the lower Santee River. Several large sturgeon were observed leaping in the river during the last two weeks in May 1967. Another was spotted in August in a deep section of the river near Lenud's Ferry (Hwy 41)(Leland 1968). Atlantic sturgeon were captured in pound nets from 27 Feburary to 20 April 1978 but were rare in occurrence (Bulak and Curtis 1978).

EDISTO RIVER - Migration of Atlantic sturgeon in 1967 occurred upstream as far as Stokes Bridge and may have continued 100 miles or more upstream, although no sturgeon have been reported in the upper reaches for many years. The clearness of its waters as well as the profusion of aquatic plants, crustaceans, and molluscs makes the Edisto River possibly the finest potential sturgeon habitat in South Carolina (Leland 1968).

SAVANNAH RIVER - All fish caught in the Savannah River are sold in Savannah, Georgia. Sturgeon are present from June through September from a point about 20 miles above the Savannah port area, which is heavily polluted, to within 50 miles of Augusta. Sturgeon are seen frequently in the areas where Brier Creek and McBean Creek join the Savannah (Leland 1968).

ST. JOHNS RIVER - The region from Palatka to and including Big Lake George is the upstream limit for Atlantic sturgeon, but its occurrence in this system is rare (McLane 1955).

3.3.8.3 Responses to Stimuli

In generaly, sturgeon curiosity is enormous - when feeding, they will stop to look at any unusual object. Indians and early settlers used this behavior to spear sturgeon in frozen lakes by attracting them with bright green or red wooden decoys (Dees 1961).

TEMPERATURE - Large sturgeon appear near South Carolina river deltas and begin moving inshore as water temperatures rise rapidly in February and March. No sturgeon are collected between 1 December (11.9 C) and 15 February (11.4 C). During summer, most sturgeon frequent areas in the river where cooler waters (deep holes) exist (Leland 1968). Offshore distributions along beaches of North Carolina may be dependent on prevailing bottom temperatures (Johnson et al. 1978).

3.3.9 Population

3.3.9.1 Sex Ratio

There is no external method of determining the sex of a sturgeon unless a female is close to spawning condition and her belly is swollen with roe (Dees 1961). Commercial catches in Winyah Bay, South Carolina, suggest a male to female ratio of 1:5 (Smith 1979).

3.3.9.2 Age Composition

No comprehensive studies have been conducted on age composition of sturgeon populations. Data collected by Holland and Yelverton (1973) estimated six age groups of Atlantic sturgeon residing in offshore North Carolina waters. Age groups were: 7-8, 9-10, 11-12, 13-14, 15-16, and 17-18. Most of the population was comprised of individuals between ages 8 and 16; age group 11-12 was most abundant.

3.3.9.3 Size Composition

NORTH CAROLINA - Atlantic sturgeon in offshore waters ranged from 40.7 to 216 cm FL and 0.6 to 113.4 kg during the 1968 to 1971 study period. Length frequency distribution indicated six peaks: 65, 80, 95, 110, 120, and 135 cm FL (Holland and Yelverton 1973). Sturgeon collected offshore during 1977 ranged in size from 87.4 to 208.3 cm FL and 5.4 to 101.3 kg (Loesch et al. 1977). Those collected in 1978 ranged from 58.4 to 86.5 cm FL and 1.1 to 5.4 kg (Johnson et al. 1978). The fork length-weight relationship for sturgeon captured from 1968 to 1971 was represented by the equation

$$W = 5.46 \times 10^{-6} L^{3.1}$$

(Holland and Yelverton 1973).

SOUTH CAROLINA - In 1979, females in Winyah Bay were considerably larger than males. Ripe females comprised 42% of the sampled catch (61 fish) by weight, while males comprised only 10%. Undeveloped females comprised the major (48%) portion of the sampled catch (Smith 1979).

3.3.9.4 Abundance and Population Status

Commercial landings in North Carolina have been in decline since the early 1970s. Landings in South Carolina have remained stable, while Georgia landings have remained low for over 30 years. Florida landings in northeast rivers have been negligible prior to World War II.

The status of Atlantic sturgeon populations in river systems along the Southeast Atlantic coast was estimated from responses to the Anadromous Fisheries Questionnaire by various State, Federal, and other agencies (Section 4). Responses (Table 3.3-1) indicate lack of knowledge about these populations. The biomass of these populations is large but the actual number of individuals within a population is probably small. Therefore, any physical or chemical disturbance potentially lethal to sturgeon and present in the system could be extremely detrimental to a population. Factors possibly important in contributing to the decline of certain populations were estimated from questionnaire responses (Table 3.3-2).

3.3.9.5 Factors Affecting Reproduction and Recruitment

Upstream habitats for spawning and nursery areas have been reduced substantially due to construction of dams, housing developments, and diversion of water flows (Leland 1968). Pollution eliminated the spawning runs in the Sampit and Lynches Rivers, South Carolina (White and Curtis 1969).

The long period required to reach maturity (up to 24 years for some females) make sturgeon populations easy targets for overexploitation. In addition, immature females participate in spawning runs each year, which suggests that some may spawn only once every two or three years (Vladykov and Greeley 1963).

At this time there are no adequate data bases or programs to assess recruitment to the fishable stock. Several life history aspects affect recruitment. Juveniles remain in natal rivers for several years and are therefore susceptible to harvest by other fisheries. Immature sturgeon participate in annual spawning runs and are therefore susceptible to exploitation while not contributing to replenishment of the stock through reproduction.

3.3.9.6 Mortality

FISHING MORTALITY - There are no good estimates of fishing mortality due to lack of recaptured individuals in mark-recapture studies. Shad fishermen illegally take a large number of small sturgeon before sturgeon season officially opens. Most are killed and thrown overboard (Leland 1968).

Table 3.3-1. Status of Atlantic sturgeon, *Acipenser oxyrhynchus oxyrhynchus*, in river systems within Region 4 based on questionnaire responses to question VI-2. S = response from marine representative; F = response from freshwater representative.

RIVER SYSTEM	STATUS
NORTH CAROLINA	
Currituck Sound	
Albemarle Sound	Declining (F)
North R.	
Pasquotank R.	
Little R.	
Perquimans R.	
Yeopim R.	
Chowan R.	Stable (S) or Declining (SF)
Meherrin R.	
Roanoke R.	Stable (S) or Declining (SF)
Cashie R.	
Scuppernong R.	
Alligator R.	
Pungo R.	
Pamlico R.	Stable or Declining (S)
Tar R.	Stable (S) or Declining (SF)
Neuse R.	Stable (S) or Declining (SF)
Trent R.	
North R.	
Newport R.	
White Oak R.	
New R.	
Cape Fear R.	Stable (S) or Declining (SF)
Northeast Cape Fear R.	Stable (S) or Declining (SF)
Black R.	
Pee Dee R.	Declining (F)
SOUTH CAROLINA	
Waccamaw R.	Not known (S), Stable (F)
Little Pee Dee R.	Stable (F)
Great Pee Dee R.	Not known (S), Stable (F)
Black R.	Not known (S), Stable (F)
Santee R.	Not known (S), Stable (F)
Cooper R.	Not known (S), Stable (F)
Ashley R.	Not known (S), Stable (F)
Edisto R.	Not known (S), Stable (F)
Ashepoo R.	Not known (S), Stable (F)
Combahee R.	Not known (S), Stable (F)
Sampit R.	Not known (S), Stable (F)
Salkehatchie R.	Stable (F)
Savannah R.	Not known (S), Stable (F)
Lynches R.	Not known (F)

Table 3.3-1. Atlantic sturgeon (cont'd.).

RIVER SYSTEM	STATUS
GEORGIA	
Savannah R.	Not known (SF)
Ogeechee R.	Not known (SF)
Altamaha R.	Not known (SF)
Oconee R.	Not known (F)
Satilla R.	Not known (S)
Ocmulgee R.	Not known (F)
St. Marys R.	Not known (S)
FLORIDA (Atlantic coast)	
St. Marys R.	Threatened (S), Stable (F)
Nassau R.	Probably never present (S), Stable (F)
St. Johns R.	Declining (SF)
Pellicer Cr.	Probably never present (S)
Moultrie Cr.	Probably never present (S)
Tomoka R.	Probably never present (S)

Table 3.3-2. Factors possibly important or very important in contributing to the decline of certain populations of Atlantic sturgeon, *Acipenser oxyrhynchus oxyrhynchus*, within Region 4 based on questionnaire responses to question I. S = response from marine representative; F = response from freshwater representative; C = response from other agencies.

NORTH CAROLINA	GEORGIA
Dams and impoundments (C)	Channelization (S)
Industrial water intakes (C)	Dredge and fill projects (S)
Location of industrial discharges (C)	Dams and impoundments (S)
Sewerage outfalls (C)	Location of industrial discharges (S)
Inadequate control of water release from dams (C)	Chemical pollution (S)
Spawning areas too accessible to fishermen (C)	Thermal effluents (S)
	Reduction in spawning habitat (S)
	Reduction in nursery areas (S)
	Poor food availability (S)
	Poor water quality (S)
SOUTH CAROLINA	**FLORIDA**
Dams and impoundments (S)	Dams and impoundments (S)
Inadequate fishway facilities (S)	Location of industrial discharges (S)
Reduction in spawning habitat (S)	Reduction in spawning habitat (S)
Poor water quality (S)	Reduction in nursery areas (S)
	Poor water quality (S)
	Non-point source pollutants (S)
	Overfishing (S)

NATURAL MORTALITY - No information was available on natural death rates for populations of Atlantic sturgeon. Leland (1968) noted that waves caused by high-speed boats probably do not damage sturgeon eggs between spawn and hatch. Very young sturgeon present in shallow areas have been observed dead or badly bruised along narrow stretches of the Edisto River, probably from wave action caused by river traffic.

IMPINGEMENT-ENTRAINMENT - No larval sturgeon were captured in a larval fish survey in the Cape Fear River from October 1976 to August 1978, nor were they entrained in cooling waters of the Brunswick Steam Electric Plant (J.O. Hackman 1981, pers. comm.). Young-of-the-year sturgeon were impinged on the traveling screens of the power plant during this period. Carolina Power and Light Company (1979) reported the following impingement figures:

September 1975 through August 1976; 30 individuals weighing 9.8 kg.

September 1976 through August 1977; 21 individuals weighing 14.9 kg.

September 1977 through August 1978; 201 individuals weighing 77.4 kg.

Adults are collected incidentally to the shad fishery in the Cape Fear Estuary (Sholar 1977b).

3.3.10 Predator-Prey Relationships

Garfish have been observed attacking schools of small sturgeon in South Carolina (Leland 1968). Sea lamprey can attack and kill large sturgeon (Scott and Crossman 1973). Sharks eat sturgeon trapped in gill nets offshore, but their role as predators on large sturgeon remains conjectural (Leland 1968).

3.3.11 Diseases

Distomiasis disease was recorded in sturgeon collected from Rarita Bay, New Jersey, caused by a digenetic trematode *Depropritis hispida* (Murawski and Pacheco 1977). Parasitic infectations of the gills, blood vessels, esophagus, gizzard, and spiral valve were described by Appy and Dadswell (1978).

3.3.12 Exploitation

3.3.12.1 Gear

NORTH CAROLINA - Gill nets and seines comprised the fishery from 1880 to 1902. Gear use then shifted to otter trawls and gill nets (Schwartz and Link 1976).

SOUTH CAROLINA - A license is required for each net, and nets must have a stretch mesh no less than 10 inches (Smith 1979). In the 1870s Swedish immigrants used long nets (600 ft) and large barges with living quarters and work-storage housing for butchering. By 1880, a butchering scow was anchored in Winyah Bay and a 15-ton schooner took dressed meat and caviar to Georgetown. Boats used to handle the 600-ft nets were flat-bottomed work boats small enough to be rowed but large enough to withstand some heavy weather (Leland 1968).

GEORGIA - The minimum gill net mesh size is six inches bar mesh; gill nets can block a maximum of 2/3 of the river (Title 45 of Georgia Code Annotated).

FLORIDA - No information available.

3.3.12.2 Fishing Areas

NORTH CAROLINA

NEUSE RIVER - Drift netting near SR 1421 and SR 1449 (Marshall 1977). Fishing for sturgeon also occurs in the ocean by trawl north of Cape Hatteras, gill net between Bogue Inlet and Bear Inlet, and gill net in both Pamlico and Albemarle Sounds. The gill net fishery between Bogue and Bear Inlets is a directed sturgeon fishery. Catches of sturgeon in the other fisheries are by-catch (Street 1981, pers. comm.).

SOUTH CAROLINA

COOPER RIVER - Yellowhouse Creek to Wadboo Creek (Leland 1968).

SANTEE RIVER - Upstream to Wilsons Landing (Leland 1968).

EDISTO RIVER - Caw Caw Swamp, Four Holes Swamp, Jennings Quarter, Youngs Island, Paris Mill, and Cooper Swamp were all locations reported by early settlers to have good fishing for sturgeon (Leland 1968).

GEORGIA

SAVANNAH RIVER - Sturgeon are caught from 20 miles upstream from the Savannah port area to within 50 miles of Augusta (Leland 1968).

ALTAMAHA AND OGEECHEE RIVERS - Both rivers support sturgeon fisheries, with the Altamaha consistently producing the highest sturgeon fishing success (C.S. Hall 1981, pers. comm.).

FLORIDA

ST. MARYS RIVER - A small sturgeon fishery supports one to two men (Williams and Grey 1975).

ST. JOHNS RIVER - Williams and Grey (1975) reported that there is no sturgeon population at present.

ST. LUCIE RIVER - Sturgeon are occasionally captured incidentally to the shad fishery (Williams and Grey 1975).

3.3.12.3 Fishing Seasons

Major sturgeon fisheries are normally associated with the spring migration, with a small fishery for downrunners in the fall.

NORTH CAROLINA - The directed ocean gill net fishery occurs in spring and fall, and the ocean trawl fishery occurs during late fall to early spring (M.W. Street 1981, pers. comm.). Gill nets are set in Albemarle and Pamlico Sounds principally during late fall through spring (M.W. Street 1981, pers. comm.). Drift netting in the Neuse River occurs from February through April, depending on the availability of fish (Marshall 1977).

SOUTH CAROLINA - The 1978-79 sturgeon season was officially open from 1 March to 1 October but all nets had to be removed from the prime fishing area (Winyah Bay jetties) by 1 May. The 1980 season opened on 15 February and all nets were to be removed from the jetty area by 15 April to reduce incidental netting of loggerhead turtles migrating to the area around mid-April (Smith 1979).

GEORGIA - Title 45 of Georgia Code Annotated sets the sturgeon season between 15 January and 1 July (R.M. Gennings 1981, pers. comm.).

FLORIDA - No information available.

3.3.12.4 Effort

NORTH CAROLINA - After 1939, commercial landings of Atlantic sturgeon in North Carolina peaked in the early 1970s, with greatest harvest occurring in 1972 (Table 3.3-3). During that year, 154,000 pounds of sturgeon were landed, representing 0.1% of the total finfish poundage landed in the State (Table 3.3-4). Dockside value of the 1972 catch was $31,000, representing 0.5% of the total finfish dockside value (Table 3.3-5, Table 3.3-6). Commercial catches have declined since 1972.

Sturgeon are not often landed in the Neuse River or the Cape Fear Estuary. Most are caught incidental to the shad fishery.

SOUTH CAROLINA - Commercial landings of sturgeon in South Carolina waters have remained fairly stable since World War II (Table 3.3-3). In recent years sturgeon landings have comprised more than one percent of the total finfish landed in the State (Table 3.3-4) for dockside values ranging from two to four percent of total finfish value (Table 3.3-6).

The last three decades of commercial sturgeon fishing have been limited to less than a dozen commercial fishermen and one dealer in Georgetown, who ships small quantities of meat and caviar to buyers in Baltimore and New York. Until about 1962 several part-time sturgeon fishermen operated on the Edisto, Combahee, Ashepoo, and Savannah Rivers. By 1967 there were no licensed fishermen operating on these rivers (Leland 1968). In Winyah Bay, five crews operated in 1978 and eight small crews operated in 1979 (Smith 1979). Statewide fisheries involved 25 to 30 fishermen running 90 nets in 1978, and 30 to 35 fishermen operating 58 nets in 1979 (Smith 1979).

GEORGIA - Commercial landings of sturgeon in Georgia waters are small compared to those of North Carolina and South Carolina (Table 3.3-3). Landings peaked in the 1950s and, with the exception of 1972, remained low ever since. Sturgeon landings normally comprise less than 0.5% of the total finfish landed annually in the State (Table 3.3-4), representing less than one percent of total finfish dockside value (Table 3.3-6).

Table 3.3-3. Sturgeon landed (thousands of pounds).

YEAR	NC	SC	GA	FL(F)	FL(W)	AL	MS	LA	TOTAL
1939	1	.	6	17	.	5	.	.	29
1940	1	3	5	3	.	0	.	0	12
1945	1	36	5	7	.	0	.	.	49
1950	11	17	15	0	0	.	.	1	45
1951	4	16	5	.	3	4	.	0	32
1952	15	24	7	.	12	0	.	.	58
1953	15	22	25	.	19	1	.	.	82
1954	10	9	21	.	3	3	.	.	46
1955	2	67	8	1	11	1	.	.	90
1956	12	80	37	.	14	1	.	.	144
1957	16	45	12	1	24	1	.	.	99
1958	22	35	4	.	15	1	.	.	77
1959	19	33	4	1	6	1	.	.	64
1960	23	42	7	.	1	.	.	.	73
1961	40	51	4	.	14	4	.	.	113
1962	49	40	2	1	12	4	.	.	108
1963	43	53	3	.	30	1	.	.	130
1964	34	64	2	.	9	1	.	.	110
1965	77	50	3	.	7	.	.	.	137
1966	59	43	1	.	8	.	.	.	111
1967	38	33	1	.	6	.	.	.	78
1968	47	44	1	.	58	.	.	.	150
1969	132	40	1	.	12	.	.	.	185
1970	120	6	4	.	18	.	.	.	148
1971	78	77	4	.	25	.	.	.	184
1972	154	68	8	.	4	.	.	.	234
1973	56	45	3	1	8	.	.	.	113
1974	93	47	2	.	4	.	.	.	146
1975	44	67	2	.	2	.	.	.	115
1976	46	.	.	.	.	.	.	.	.
1977	30	.	.	.	.	.	.	.	.
1978	32	.	.	.	.	.	.	.	.
1979	41	.	.	.	.	.	.	.	.
1980	30	.	.	.	.	.	.	.	.

Table 3.3-4. Pounds landed (%) of sturgeon in the total commercial catch of finfish by state.

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA
1939	0.00	.	0.18	0.01	.	0.10	.	.
1940	0.00	0.23	0.69	0.00	.	0.00	.	0.03
1945	0.00	1.19	0.42	0.00	.	0.01	.	.
1950	0.01	0.62	1.76	0.00	0.00	.	.	0.00
1951	0.00	0.16	0.61	.	0.01	0.10	.	0.00
1952	0.01	0.33	0.87	.	0.02	0.01	.	.
1953	0.01	0.67	3.16	.	0.04	0.03	.	.
1954	0.01	0.16	2.48	.	0.01	0.07	.	.
1955	0.00	0.73	0.85	0.00	0.02	0.03	.	.
1956	0.00	0.95	5.26	.	0.03	0.03	.	.
1957	0.01	0.37	1.29	0.00	0.04	0.03	.	.
1958	0.01	0.87	0.40	.	0.02	0.03	.	.
1959	0.01	0.36	0.38	0.00	0.01	0.02	.	.
1960	0.01	0.65	0.45	.	0.00	.	.	.
1961	0.02	0.64	0.32	.	0.02	0.11	.	.
1962	0.03	0.56	0.19	0.00	0.02	0.09	.	.
1963	0.02	0.75	0.36	.	0.04	0.02	.	.
1964	0.02	0.91	0.30	.	0.01	0.01	.	.
1965	0.04	0.52	0.32	.	0.01	.	.	.
1966	0.03	0.41	0.12	.	0.01	.	.	.
1967	0.02	0.45	0.10	.	0.01	.	.	.
1968	0.02	0.49	0.06	.	0.08	.	.	.
1969	0.07	0.72	0.11	.	0.02	.	.	.
1970	0.08	0.19	0.37	.	0.03	.	.	.
1971	0.07	1.61	0.41	.	0.04	.	.	.
1972	0.10	1.30	0.74	.	0.01	.	.	.
1973	0.05	1.16	0.36	0.00	0.01	.	.	.
1974	0.05	1.70	0.27	.	0.01	.	.	.
1975	0.02	1.86	0.27	.	0.00	.	.	.
1976	0.02	.	.	.	.	.	.	.
1977	0.01	.	.	.	.	.	.	.
1978	0.01	.	.	.	.	.	.	.
1979	0.01	.	.	.	.	.	.	.
1980	0.01	.	.	.	.	.	.	.

Table 3.3-5. Dockside value of sturgeon (thousands of dollars).

YEAR	NC	SC	GA	FL(F)	FL(W)	AL	MS	LA	TOTAL
1939	0	.	1	2	.	0	.	.	3
1940	0	0	1	0	.	0	.	0	1
1945	0	14	1	2	.	0	.	.	17
1950	3	4	5	0	0	.	.	0	13
1951	1	4	0	.	0	1	.	0	6
1952	4	7	2	.	2	0	.	.	15
1953	4	4	5	.	5	1	.	.	19
1954	2	2	4	.	1	1	.	.	10
1955	.	13	3	1	2	1	.	.	20
1956	2	16	10	.	3	1	.	.	32
1957	2	9	2	1	5	1	.	.	20
1958	3	7	1	.	3	1	.	.	15
1959	3	5	1	1	1	1	.	.	12
1960	4	7	2	.	1	.	.	.	14
1961	6	9	1	.	2	1	.	.	19
1962	7	6	1	1	2	1	.	.	17
1963	9	8	1	.	4	1	.	.	23
1964	7	10	1	.	2	1	.	.	20
1965	15	8	1	.	1	.	.	.	25
1966	8	8	1	.	2	.	.	.	19
1967	5	6	1	.	1	.	.	.	13
1968	7	8	1	.	9	.	.	.	25
1969	14	7	1	.	61	.	.	.	83
1970	19	1	1	.	2	.	.	.	23
1971	13	15	2	.	4	.	.	.	34
1972	31	18	2	.	1	.	.	.	52
1973	10	13	1	1	1	.	.	.	26
1974	16	20	1	.	1	.	.	.	37
1975	8	23	1	.	1	.	.	.	33
1976	10	.	.	.	.	.	.	.	.
1977	5	.	.	.	.	.	.	.	.
1978	7	.	.	.	.	.	.	.	.
1979	12	.	.	.	.	.	.	.	.
1980	11	.	.	.	.	.	.	.	.

Table 3.3-6. Dockside value (%) of sturgeon in the total commercial catch of finfish by state.

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA
1939	0.01	.	1.58	0.12	.	0.23	.	.
1940	0.00	0.71	1.16	0.01	.	0.00	.	0.03
1945	0.01	4.64	0.77	0.02	.	0.00	.	.
1950	0.08	1.88	3.79	0.00	0.01	.	.	0.00
1951	0.03	0.59	0.13	.	0.01	0.11	.	0.00
1952	0.10	2.23	1.31	.	0.03	0.01	.	.
1953	0.11	2.27	3.29	.	0.09	0.15	.	.
1954	0.05	0.97	2.84	.	0.02	0.16	.	.
1955	.	3.93	2.34	0.03	0.03	0.20	.	.
1956	0.04	3.07	9.62	.	0.05	0.22	.	.
1957	0.04	1.76	1.49	0.03	0.09	0.24	.	.
1958	0.05	2.30	0.74	.	0.05	0.19	.	.
1959	0.06	1.47	0.61	0.03	0.02	0.16	.	.
1960	0.10	1.81	0.83	.	0.01	.	.	.
1961	0.14	1.24	0.67	.	0.03	0.08	.	.
1962	0.21	0.96	0.29	0.01	0.03	0.08	.	.
1963	0.21	1.36	0.75	.	0.06	0.06	.	.
1964	0.15	1.40	0.37	.	0.03	0.05	.	.
1965	0.30	0.80	0.52	.	0.01	.	.	.
1966	0.16	1.21	0.65	.	0.02	.	.	.
1967	0.10	1.51	0.36	.	0.01	.	.	.
1968	0.15	1.39	0.27	.	0.10	.	.	.
1969	0.28	1.27	0.21	.	0.60	.	.	.
1970	0.42	0.26	0.45	.	0.02	.	.	.
1971	0.30	2.80	0.77	.	0.04	.	.	.
1972	0.53	2.51	0.72	.	0.00	.	.	.
1973	0.12	1.96	0.41	0.01	0.01	.	.	.
1974	0.15	4.07	0.20	.	0.00	.	.	.
1975	0.06	3.65	0.36	.	0.00	.	.	.
1976	0.07	.	.	.	.	.	.	.
1977	0.03	.	.	.	.	.	.	.
1978	0.03	.	.	.	.	.	.	.
1979	0.04	.	.	.	.	.	.	.
1980	0.03	.	.	.	.	.	.	.

FLORIDA - Commercial landings for sturgeon in northeast rivers have been reported sporadically since 1950. A very small sturgeon fishery is still in operation in the St. Marys River, employing one to two men (Williams and Grey 1975).

3.3.13 Protection and Management

3.3.13.1 North Carolina

At present there is no program for protection and management of sturgeon stocks in North Carolina waters.

3.3.13.2 South Carolina

The coincidence of the shad and sturgeon fishing seasons, and the resulting kill of young sturgeon by shad netters, could be a major factor in sturgeon population decline (Leland 1968). A three-year closed season for sturgeon was imposed by the General Assembly of 1937 and covered years 1938, 1939, and 1940. The law was repealed 21 March 1940; however, Federal and State fishery statistics clearly showed that the law was not obeyed. Shad fishermen illegally take a large number of small sturgeon (1.4 to 4.4 kg) in their nets. Since there is practically no market for small sturgeon, most are clubbed to death and thrown overboard (Leland 1968).

South Carolina fishermen must purchase a license for each net, and dealers are required to purchase a sturgeon processing and marketing license (Smith 1979). In 1978, 18 people purchased 90 net licenses and five buyers and shippers purchased sturgeon licenses. In 1979, 15 people purchased 58 net licenses and only two licenses were issued for buyers and shippers (Smith 1979).

The South Carolina sturgeon fishery is regulated by law. Open season extends from 1 March to 1 October. Minimum mesh size is 10 inches stretch mesh. A monthly catch report is required from the license holder. It is illegal to have decomposed sturgeon in nets. Fishermen cannot leave nets on stream banks for more than three days after the season closes.

Leland (1968) suggested a rational approach to solving the conflict of interest between shad fishermen and protection of sturgeon populations. At the time shad nets were permitted in estuarine areas during the period when sturgeon were moving inshore from the ocean. Mesh size in use caught large numbers of small sturgeon, which were killed by shad fishermen. Leland recommended moving the shad fishery further upstream to protect sturgeon, which remain in the lower estuary.

Another method which could be used to protect sturgeon stocks would involve the establishement of "fish life areas" comparable to wildlife areas established for protecting birds and land animals. The South Carolina Code of Laws (28-717) allows the establishment of river fish sanctuaries not over two miles in length for five-year periods. Such a sanctuary was in existence in 1967 on Little Pee Dee River near Gallivant's Ferry and was the only one listed by the South Carolina Wildlife Resources Department that affected a sturgeon river (Leland 1968).

3.3.13.3 Georgia

The legal minimum bar-mesh size for gill nets used for Atlantic sturgeon fishing is six inches. Legal shad nets do take small sturgeon, but all fish other than shad must be released unharmed back into the water from which they were taken (R.M. Gennings 1981, pers. comm.).

3.3.13.4 Florida

The minimum mesh size legal for use in gill nets is 10 inches stretch.

3.3.13.5 Culture

South Carolina State and Federal biologists made history when they successfully spawned and hatched Atlantic sturgeon artificially in March 1979 at the Orangeburg National Fish Hatchery. Fertilized eggs were obtained by induced spawning from two females weighing 67.6 and 76.6 kg (1.8 and 2.1 m FL) and one male donated by a commercial fisherman. The females were captured in Winyah Bay near Georgetown and transported to Orangeburg in a specially designed sturgeon transport truck. Although only a relatively small number of eggs hatched, the event was considered successful. Previous attempts to spawn Atlantic sturgeon were conducted at northern fish processing plants from 1875 to 1909. Some success was achieved, but the hatching programs were abandoned after several years of effort.

Culture of juveniles and holding of brood stock in ponds may be very feasible. Juveniles 54 to 66 cm FL and one to two kg were successfully held in earthen ponds for over one year, and one adult 193 cm FL weighing 72 kg was held for an indefinite period (Smith 1979). Russian scientists experimenting with several European species have not determined if hatchery-reared sturgeon can reach sexual maturity in captivity (Mailvan and Alekperov 1976).

3.3.13.6 Tagging

Tagging programs by various State and Federal agencies have had limited success in defining growth rates, migratory patterns, and mortality rates of Atlantic sturgeon populations. Studies have indicated that Carlin tags are retained well and do not significantly damage fish (Smith 1979). Holland and Yelverton (1973) reported tagging 187 sturgeon with Floy dart tags; 15 fish were recaptured.

3.3.13.7 Recommendations

Manea (1970) observed that sturgeon stocks in many places throughout the world have diminished dramatically over the last century due to intense and irrational catches of sturgeon, damming of rivers, and destruction of fry by use of traps and gill nets. Manea recommended the following measures be taken to restore and preserve sturgeon stocks:

1) Protect and improve natural breeding zones and protect fry.

2) Interdict, limit, and rationally organize sturgeon catches according to river system and season.

3) Stock, by plan, rivers which have been dammed with fry reared in special ponds.

Developing spawning and rearing techniques for Atlantic sturgeon may be directly applicable for culturing endangered species such as shortnose sturgeon (Smith et al. 1980).

3.4 Gulf Coast Sturgeon (*Acipenser oxyrhynchus desotoi*)

3.4.1 Historical Significance

The Gulf coast sturgeon and the Atlantic sturgeon (*Acipenser oxyrhynchus oxyrhynchus*) are allopatric subspecies having been separated by the emergence of peninsular Florida and maintained by the thermal barrier of the Gulf Stream around south Florida (Rivas 1954). Body differences include a slightly shorter head length and longer pectoral fins in Gulf sturgeon, the shape of scutes, and length of the spleen (Vladykov and Greeley 1963). Both subspecies are classified as threatened by the Florida Committee on Rare and Endangered Plants and Animals (Gilbert 1978). Gulf sturgeon is classified as a species of special concern by the Florida Game and Freshwater Fish Commission (Wooley et al. 1981a).

Gulf sturgeon were once widely distributed throughout the Gulf of Mexico but populations have steadily declined due to degrading water quality, loss of suitable habitat, and overexploitation. The first active sturgeon fishery in Florida began in Tampa Bay (Hillsborough River) in 1886 and lasted only during the winters of 1886 through 1889. Fishermen landed 1500 fish in 1886-87 and 2000 fish in 1887-88; only seven fish were landed in 1888-89 and the sturgeon population was virtually eliminated (Williams and Grey 1975). Franklin County, Florida, became a prominent meat and caviar producer by 1900; fishing first began on the Ocklockonee River in 1898, and landings for the Ocklockonee and Apalachicola Rivers were first reported in statistical records for 1900 (Huff 1975). Sturgeon landings were estimated between 20,000 and 60,000 pounds from the Apalachicola River prior to 1917. Smith (1917) warned that the average size of sturgeon landed was decreasing and the species was nearing extinction. In 1901, commercial sturgeon fisheries were also started in the Choctawhatchee River and Bay, Escambia River and Bay, and the Blackwater River (Huff 1975).

The Suwannee River presently supports the largest and perhaps the only remaining viable spawning population of Gulf sturgeon in the Gulf of Mexico. An active gill net fishery employing 30 men was started in the Suwannee River in November 1896; the 1897 catch was 9,254 pounds worth $331 and comprised the entire catch in Florida for that year (Huff 1975). Although the history of most U.S. and Florida sturgeon fisheries has been of overfishing and decline, the Suwannee fishery has remained viable due to limitation of fishing pressure by geographical river characteristics and fishing techniques (Huff 1975).

The Apalachicola River has also had a long history of sturgeon fishing. A brief review of the Apalachicola sturgeon fishery was presented by Wooley et al. (1981a): "The fishery declined from an average of 9,000 to 27,000 kg yr^{-1} before 1917 to no substantial commercial fishery in recent years (U.S. Commission of Fish and Fisheries 1902, National Marine Fisheries Service 1977). The U.S. Army Corps of Engineers (1978) stated that the commercial fishery in the Apalachicola River system effectively ended in 1970, when only five fish were taken. In 1962 and for a few years afterward, a hook-and-line sport fishery developed below the Jim Woodruff Dam, where the sturgeon were blocked from any further migration upstream."

3.4.2 Distribution

3.4.2.1 Range

Gulf sturgeon are limited to the Gulf of Mexico, northern coast of South America, and possibly Bermuda (Vladykov and Greeley 1963).

3.4.2.2 Eggs

Sturgeon eggs are large (2.6 to 3.0 mm in diameter), demersal and adhesive; the external membrane of a postspawned egg absorbs water and becomes sticky within one hour (Vladykov 1963 and personal communication cited in Huff 1975). Apparently these eggs have sufficient gravity for them to remain relatively unaffected by swift river currents (Huff 1975).

3.4.2.3 Juveniles

Common sturgeon may begin anadromous migrations as yearlings (Huff 1975). Larvae and very young sturgeon have never been captured or observed in the Suwannee River; hence localized distributions are unknown. A larval Gulf sturgeon was collected in the Apalachicola River at River Km 167.7 (3.3 km below Jim Woodruff Dam) on 11 May 1977, representing the first recorded capture of a larval Gulf of Mexico sturgeon (Wooley et al. 1981a, 1981b).

3.4.2.4 Adults

Gulf sturgeon probably enter most major river systems north and west of and including the Suwannee River, Florida; reports of sturgeon were received as far south as Charlotte Harbor, Florida, but probably belonged to populations of northern Gulf rivers (Williams and Grey 1975). Historically, Gulf sturgeon were found as far

south as Tampa Bay, Florida, but commercial fisheries eliminated the population by 1889 (Williams and Grey 1975).

3.4.3 Reproduction

3.4.3.1 Maturity

Sexes begin to differentiate at approximately 500 to 700 mm fork length. Oocyte development (Stage I and II) in females appears to start around 670 mm. Differentiation occurs at ages II, III, and IV (Huff 1975). Spawning females enter the Suwannee River fishery at ages VIII to XII and males enter at ages VI to IX, although younger sturgeon are present in pre- and post-spawning migrations (Huff 1975).

3.4.3.2 Mating

No information available.

3.4.3.3 Fertilization

Eggs are released in open waters of rivers where they are fertilized.

3.4.3.4 Fecundity

No information available.

3.4.4 Spawning

3.4.4.1 Season and Location

Suitable spawning habitat occurs in the Suwannee River in areas from Ellaville upstream to White Springs and possibly further depending on river height; however, no spawning activity has been observed and no suitable spawning areas have been identified below Ellaville (Huff 1975). The upper Apalachicola River (River Km 160 and upstream) may be an important sturgeon spawning area, partly because of the presence of remnant limestone shoal areas (Wooley et al. 1981a).

Spawning occurs from late May through October in the Suwannee River, Florida. Observations on Apalachicola River sturgeons by Wooley et al. (1981a, 1981b) suggest spawning occurs during late April and early May at the end of spring high water.

3.4.4.2 Temperature

A flowing male was collected at a water temperature of 20.6 C in the Apalachicola River (Wooley et al. 1981a).

3.4.4.3 Spawning Habitat

Sturgeon spawn over hard bottom in areas of shallow running water (shoal areas) and in pools below waterfalls (Dees 1961, Vladykov 1963). Spawning habitat in the Apalachicola River may consist of remnant limestone shoal areas 1.7 m deep (Wooley et al. 1981a).

3.4.4.4 Diel Spawning Patterns

No information available.

3.4.5 Life History - Eggs and Larvae

3.4.5.1 Hatching and Growth

Hatching and development may be similar to Atlantic sturgeon.

3.4.5.2 Hardiness

There are no published accounts concerning the hardiness of Gulf sturgeon eggs and larvae as related to variables salinity, temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport. The only larval Gulf sturgeon ever collected in Gulf of Mexico waters was captured one to two days after hatching in the Apalachicola River, Florida. The area of collection contained a sand and gravel substratum with a water temperature of 23.9 C, water depth of 4.2 m, 365 m^3 s^{-1} water flow, and 67 cm s^{-1} velocity (Wooley et al. 1981b).

3.4.5.3 Swimming Ability

Sac fry behavior may be similar to that of Atlantic sturgeon.

3.4.5.4 Chemical Tolerances

No information available.

3.4.5.5 Pressure

No information available.

3.4.6 Life History - Juveniles

3.4.6.1 Nutrition and Growth

FEEDING - Juveniles captured in the Alligator Pass, Suwannee River, had ingested primarily gammaridean amphipods (Family Haustoridae), which are generally associated with bottoms similar to submerged tidal sand banks where the juveniles were captured. Other food (less than five percent) included isopods, midge larvae, mud shrimp (Callianassidae), an eel (Moringua sp.), and some unidentifiable animal or vegetable matter (Huff 1975).

GROWTH - Growth rates were calculated for the Suwannee River population for age groups I through XVII. Length-weight relationships were significantly different between spring and fall fishing seasons and between sexes. The age-length relationship was calculated as

$$FL = 369.2326\ AGE^{0.5284}$$

(Huff 1975).

METABOLISM - No information available.

3.4.6.2 Hardiness

Little is known concerning the effects of the following variables on juvenile Gulf sturgeon: salinity, temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport.

3.4.6.3 Swimming Ability

No information available.

3.4.6.4 Chemical Tolerances

No information available.

3.4.6.5 Pressure

No information available.

3.4.7 Life History - Adults

3.4.7.1 Longevity

Gulf sturgeon are long-lived. The oldest adult captured by Huff (1975) in the Suwannee River was a female approximately age 42.

3.4.7.2 Nutrition and Growth

FEEDING - No information available.

GROWTH - The age-length relationship of Gulf sturgeon in the Suwannee River (age classes I through XVII) was presented in Section 3.4.6.1.

METABOLISM - No information available.

3.4.7.3 Hardiness

Information is lacking concerning the effects of the following variables on adult Gulf sturgeon: salinity, temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport.

3.4.7.4 Swimming Ability

No information available.

3.4.7.5 Chemical Tolerances

No information available.

3.4.7.6 Pressure

No information available.

3.4.8 Behavior

3.4.8.1 Juvenile Migration and Local Movement

Small Gulf sturgeon (2.3 kg or less) were observed by fishermen to school on the surface and rapidly leave the Suwannee River in December 1973 (Huff 1975). Sightings and capture of juveniles in Alligator Pass in spring and the sighting of juveniles leaving the river in December suggested that they may have participated in pre- and post-spawning migrations (Huff 1975). Since larvae and very young sturgeon have not been collected in the Suwannee River, no information is available concerning frequented habitats or ambient water qualities normally encountered in localized areas[1]. One larval Gulf sturgeon 9.71 mm FL was captured in the upper Apalachicola River (River Km 166.4) over a sand and gravel bottom on 11 May 1977 (Wooley et al. 1981b).

1. Letter from James A. Huff, Senior Biologist, to Tom Swihart, Department of Environmental Regulation, State of Florida, 9 September 1980.

3.4.8.2 Adult Migration and Local Movement

Adult Gulf sturgeon exhibit a pre-migration in the spring and a post-migration in the fall. The migration routes selected by adults appear to be dependent on the sex and season. Larger females seek shallow water during upstream movement and deep water when moving downstream (Huff 1975). Localized riverine distributions and ocean migratory patterns are not known.

Juvenile and adult Gulf sturgeon have been observed by Service personnel in the Apalachicola River. One juvenile and four adults were captured in the upper Apalachicola River above River Km 100 between late April and mid-September 1976 through 1980. One of the adults was a ripe male caught over a limestone shoal area in water 20.6 C and 1.7 m deep. The other three adults were captured during the summer months in water four to five m deep. These adults were believed to have spawned in the upper river during late spring or early summer and had not yet started their fall post-spawning migration downriver. During August and October, two sturgeon were collected in lower reaches of the Apalachicola River below River Km 100. One was a juvenile sturgeon (264 mm FL) captured in the Jackson River (Intracoastal Waterway) at the mouth of Murphy Creek, a brackish marsh area. The other was a sub-adult (505 mm FL) collected at a water temperature of 21.9 C during presumed post-spawning migration in the lower river (Wooley et al. 1981a).

3.4.8.3 Responses to Stimuli

No information available.

3.4.9 Population

3.4.9.1 Sex Ratio

Sex ratios determined from gill net landings may be biased due to the different migration routes selected by adults as determined by sex and season. Huff (1975) reported the following results of sex ratio comparisons for the Suwannee River:

Season	1972	1973
Spring	0.354, P = 0.05	0.402, P = 0.05
Fall	0.567, non sig.	0.519, non sig.

Spring sex ratios were significantly different ($P = 0.05$) from 1:1, and fall ratios were not significantly different (Huff 1975).

3.4.9.2 Age Composition

No comprehensive studies have been conducted on the age composition of Gulf sturgeon populations. In the Suwannee River, Gulf sturgeon enter the fishery at ages IV and V and become significantly exploited by age VI (Huff 1975).

3.4.9.3 Size Composition

No information available.

3.4.9.4 Abundance and Population Status

Commercial landings of Gulf sturgeon in Alabama, Mississippi, and Louisiana have been negligible since the 1950s, and landings in Gulf coastal waters of Florida dropped sharply in the early 1970s.

The status of Gulf sturgeon populations in river systems along the Gulf of Mexico was estimated from the responses given by the various marine and freshwater representatives to our Anadromous Fisheries Questionaire (Section 4). These responses (Table 3.4-1) indicate lack of knowledge about these populations. The only Gulf sturgeon population presently believed to be stable inhabits the Suwannee River, Florida. Dams, channelization, and poor water quality appear to be major factors contributing to the decline of Gulf sturgeon populations (Table 3.4-2).

3.4.9.5 Factors Affecting Reproduction and Recruitment

Most females (72.5%) in the Suwannee River were immature (Huff 1975).

"...Certain life history characteristics of Gulf sturgeon make them particularly sensitive to environmental or ecological damage and degradation. Most notably are: 1) the relatively long period of time for individuals to reach sexual maturity (12 to 16 years for females, 9 to 12 years for males) and 2) the participation of all year classes in the spawning run whether or not each individual sturgeon is capable of spawning. Consequently, female sturgeon spawned in 1980 will not be capable of reproduction until 1992-1996. However, each year they will participate in the spawning run and will be subjected to all natural and man-induced mortalities."[1]

Table 3.4-1. Status of Gulf sturgeon, <u>Acipenser oxyrhynchus desotoi</u>, in river systems within Region 4 based on questionnaire responses to question VI-2. S = response from marine representative; F = response from freshwater representative.

RIVER SYSTEM	STATUS
FLORIDA (Gulf coast)	
Hillsborough R.	No longer present (S)
Suwannee R.	Stable (S)
Apalachicola R.	Threatened (S), Declining (F)
Ocklockonee R.	No longer present (F)
Escambia R.	
ALABAMA	
Alabama R.	Not known (S), No longer present (F)
Tombigbee R.	Not known (S), No longer present (F)
Perdido R.	Not known (S)
Bon Secour R.	Not known (S)
Fish R.	Not known (S)
Magnolia R.	Not known (S)
Dog R.	Not known (S)
Fowl R.	Not known (S)
Tennessee R.	No longer present (F)
Chattahoochee R.	
Coosa R.	No longer present (F)
Tallapoosa R.	No longer present (F)
MISSISSIPPI	
Pascagoula R.	Not known
Tchouticabouffa R.	Not known
Biloxi R.	Not known
Wolf R.	Not known
Jourdan R.	Not known
Pearl R.	Not known
LOUISIANA	
Pearl R.	Not known
Bayou LaCombe	Not known
Tchefuncte R.	Not known
Tangipahoa R.	Not known
Tickfaw R.	Not known
Amite R.	Not known
Mississippi R.	Not known
Atchafalaya R.	Not known
Vermillion R.	Not known
Mermentau R.	Not known
Calcasieu R.	Not known
Sabine R.	Not known

Table 3.4-2. Factors possibly important or very important in contributing to the decline of certain populations of Gulf sturgeon, *Acipenser oxyrhynchus desotoi*, within Region 4 based on questionnaire responses to question I. S = response from marine representative; F = response from freshwater representative.

FLORIDA (Gulf coast)

- Channelization (S)
- Dams and impoundments (S)
- Location of industrial discharges (S)
- Inadequate fishway facilities (S)
- Reduction in spawning habitat (S)
- Reduction in nursery areas (S)
- Poor water quality (S)
- Proposed phosphate strip-mining (S)

ALABAMA

- Bulkheading (F)
- Dams and impoundments (FS)
- Location of industrial discharges (FS)
- Road construction (S)
- Low oxygen levels (S)
- Sewerage outfalls (S)
- Inadequate fishway facilities (FS)
- Inadequate control of water release from dams (F)
- Reduction in spawning habitat (F)
- Reduction in nursery areas (F)
- Poor food availability (S)
- Poor water quality (FS)

MISSISSIPPI

- Inadequate information

LOUISIANA

- Channelization
- Dams and impoundments

3.4.9.6 Mortality

SUWANNEE RIVER - The percent survivorship between successive years for sturgeon ages VIII through XII estimated as 53.73% (Huff 1975). Because of the enormous amount of biomass tied up in each individual within the population, several seasons of overexploitation can virtually eliminate an entire population; i.e., the sturgeon population of Tampa Bay (1886-1889).

3.4.10 Predator-Prey Relationships

No information available.

3.4.11 Diseases

No information available.

3.4.12 Exploitation

3.4.12.1 Gear

FLORIDA - Six different techniques have been used to capture Gulf sturgeon in the Suwannee and other rivers of northwest Florida. Drift nets were used exclusively through 1929; in 1972 they accounted for only 13% of the entire annual catch. Pound nets and runaround gill nets were introduced in the Suwannee River in 1930-31. In 1932, pound nets were discontinued and replaced by more effective trammel nets. By 1945, only trammel nets were used in the Suwannee. Presently, anchored gill nets are the principal gear used; drift gill nets are used in eddies of East Pass upstream to Ellaville but are not extensively employed due to increased effort and operational costs required (Huff 1975). Trammel nets with 10-inch mesh are employed in Alligator Pass to capture juveniles. Anchored gill nets are relatively unselective, capturing sturgeon between 38 to 188 cm FL weighing approximately 3.6 to 58.2 kg (Huff 1975). A hook-and-line fishery has been established in the tailrace of Jim Woodruff Lock and Dam.

3.4.12.2 Fishing Areas

APALACHICOLA RIVER - Gulf sturgeon migrate more than 322 km upstream but are netted only in the first 48 km. A hook-and-line sport fishery is located at the base of Jim Woodruff Dam (Huff 1975).

SUWANNEE RIVER - The present fishing pressure is limited by geographical characteristics of the river and by fishing techniques. Subadults and adults are gill-netted in East Pass. Juveniles are trammel-netted in Alligator Pass. Of several river entrances, only East Pass is commercially exploited leaving the other potential migration routes unfished (Huff 1975). Drift gill-netting occurs from the river mouth upstream to Ellaville but is not extensively employed (Huff 1975).

CHOCTAWHATCHEE RIVER - As of 1979, gill-netting at the river mouth was still performed by one to two commercial fishermen (Barkaloo 1981, pers. comm.).

3.4.12.3 Fishing Seasons

Fishing seasons for Gulf sturgeon historically have varied among areas.

TAMPA BAY - The early fishery probably occurred in December, January, and February but was abandoned after three years when stocks were thoroughly depleted (Huff 1975).

SUWANNEE RIVER - The early Gulf sturgeon fishery was 1 February to 1 May and excluded exploitation of the fall migration (Huff 1975).

APALACHICOLA RIVER - At present, commercial sturgeon fishing occurs from mid-April to the end of June. A hook-and-line fishery that developed at the base of Jim Woodruff Dam in August 1962 is conducted from April through June and from August through September (Huff 1975).

3.4.12.4 Effort

FLORIDA - Commercial landings of Gulf sturgeon along the Florida Gulf coast peaked in 1902, when 343,291 pounds of sturgeon meat and caviar were processed (Table 3.4-3). Commercial landings during the 1900s have been sporadic. A recent peak in commercial landings occurred in 1968 when 58,000 pounds of Gulf sturgeon (Table 3.3-3) were landed in west Florida, representing nearly 0.1% of the total pounds of finfish landed in that year on the Florida Gulf coast (Table 3.3-4). The 1968 landings brought a dockside value of $9,000 (Table 3.3-5) representing 0.1% of total finfish dockside value for west Florida (Table 3.3-6).

Table 3.4-3. Historical catch statistics [illegible] Gulf sturgeon in Florida, years 1886 through 1945 (from Huff 1975).

YEAR	LOCATION	MEAT (pounds)	VALUE ($)	CAVIAR (pounds)	VALUE ($)	TOTAL (pounds)
1886-87	Tampa Bay	1,500[1]		5,000		
1887-88	Tampa Bay	2,000[1]		6,300		
1888-89	Tampa Bay	7[1]				
1897	Levy Co.	9,254	331			9,254
1900	Suwannee R.	44,000	2,664	1,260	1,008	165,000
	Ochlockonee R.	37,000	2,322	850	595	
	Apalachicola R.	84,000	4,800	2,160	1,152	
1902	Escambia Co.	259,171	3,491	4,326	1,753	343,291
	Franklin Co.	74,120	1,950	3,706	1,073	
	Levy Co.	10,000	250	500	200	
1917[2]	Apalachicola R. & Bay	20,000 to 60,000	2,000 to 6,000			
1918	Escambia Co.	2,250	270			4,915
	Franklin Co.	1,215	60			
	Levy Co.	1,450	290			
1923	West Coast	7,400	1,088			7,400
1927	West Coast	7,669	932			7,669
1929	Escambia Co.	3,604	432			16,247
	Franklin Co.	9,599	1,056			
	Levy Co.	3,044	609			
1930	Franklin Co.	6,119	857			13,126
	Levy Co.	7,007	1,274			
1931	Franklin Co.	3,041	276			8,260
	Levy Co.	5,219	949			
1932	Franklin Co.	5,941	447			14,734
	Levy Co.	8,793	639			
1933	West [illegible]	4,379	199			4,379
1945	Franklin Co.	3,700	925			7,200
	Dixie Co.	3,500	675			

[1] Tampa Bay landings were reported as number of fish.
[2] Estimated annual landings for unspecified previous years.

The recreational fishery for Gulf sturgeon in Florida has been small but important. A hook-and-line fishery developed in the tailrace of Jim Woodruff Lock and Dam in August 1962 (Huff 1975).

ALABAMA - The commercial fishery for Gulf sturgeon in Alabama waters historically has been smaller than the Florida Gulf coast fishery. Reported landings rarely exceeded 4,000 pounds (Table 3.3-3) or 0.1% of the total finfish landed in Alabama (Table 3.3-4). Dockside value of Gulf sturgeon averaged about $1,000 (Table 3.3-5) and comprised up to 0.24% of total finfish dockside value in 1957 (Table 3.3-6). No commercial landings of Gulf sturgeon have been reported from Alabama waters since 1964.

MISSISSIPPI - No commercial landings of Gulf sturgeon have been reported from Mississippi waters since 1939, and no historical catch statistics could be located for years prior to 1939.

LOUISIANA - Commercial landings of Gulf sturgeon were reported sporadically from Louisiana during the 1940s and early 1950s, and no landings were reported after 1951 (Table 3.3-3). Commercial landings rarely exceeded 1,000 pounds and $500 in value. Historical catch statistics for years prior to 1939 could not be located.

3.4.13 Protection and Management

Huff (1975) believed that the Suwannee River supports the largest remaining viable spawning population of Gulf sturgeon in the Gulf of Mexico. Populations in the Apalachicola, Choctawhatchee, Yellow, and other west Florida rivers still were exploited commercially in the 1960s and early 1970s (Barkaloo 1981, pers. comm.). Current fishing pressure in the Suwannee River is limited only by the unique geographical characteristics of the river and by fishing techniques. Illegal trammel-netting of juveniles with mesh size less than 10 inches was observed by Huff (1975) and represents an intolerable threat to the fishery. Huff stated that continued harvesting of stocks on a commercial basis is not endangered as long as current levels of exploitation by 10-inch mesh gill nets are not exceeded greatly.

The following quotation is a portion of a memorandum from James Huff to Mr. Tom Swihart, Department of Environmental Regulation for the State of Florida:

"Gulf sturgeon poulations could (also) be significantly impacted by slow, barely detectable, but cumulative, long-term degradation of in-river water quality and habitat... It is unknown where very young sturgeon concentrate and what ambient water quality they normally encounter in localized areas. If degradation occurs which affects larval and postlarval populations, it will be several years before population declines are detected in catch statistics.

"Gulf sturgeon are designated a 'species of special concern' by the State of Florida. Additionally, the U.S. Fish and Wildlife Service has recognized the vulnerability of this species and has begun procedures which will lead to its being listed as threatened or endangered under the Endangered Species Act. If this occurs, the Suwannee River's role as critical habitat will be considerably upgraded.

"In light of the proposed increased discharge of mining and chemical wastes into the Suwannee River, the following actions are desirable and highly recommended:

1) Designate Gulf sturgeon as an 'indicator species' requiring long-term intensive monitoring for evidence of degrading habitat and declining populations.

2) Initiate a research program to identify specific areas of suitable habitat utilized by adult, spawning Gulf sturgeon in the upper river.

3) Initiate a research program to identify specific areas utilized by larval and postlarval sturgeon.

4) Identify environmental and water quality standards which insure the survival and continued high production of eggs, larvae, juveniles, and adults.

"The Suwannee River is the population center of sturgeon in the Gulf of Mexico. If in-river spawning habitat becomes unsuitable, for whatever reason, then Gulf sturgeon populations will undoubtably suffer an inevitable decline to near or complete extinction."

3.5 Shortnose Sturgeon (*Acipenser brevirostrum*)

3.5.1 Historical Significance

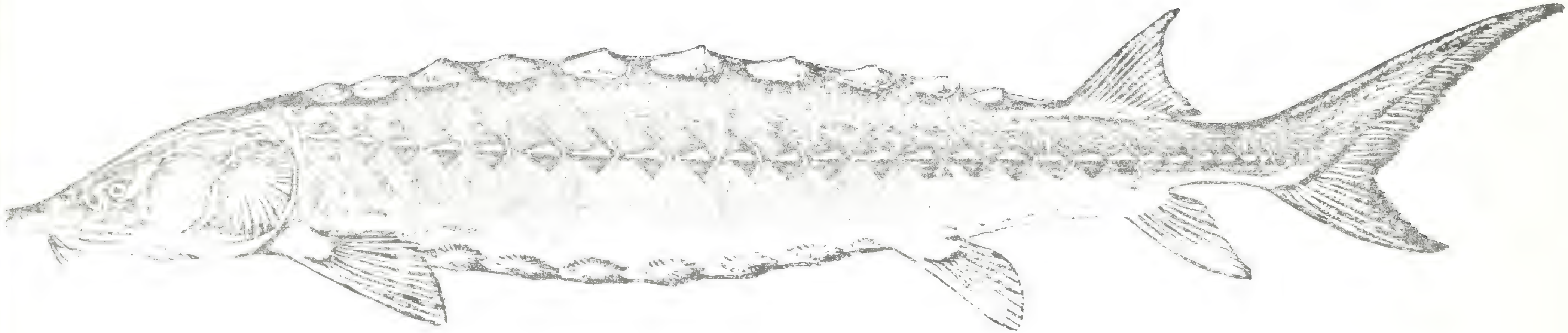
The shortnose sturgeon - also known as blunt-nosed, round-nosed, and small sturgeon - is considered an endangered species in the United States (Miller 1972) and as a rare and possibly endangered species in Canada (McAllister 1970). Its distribution is restricted to the east coast of North America and ranges from Saint John River, New Brunswick, Canada, to the St. Johns River, Florida (Vladykov and Greeley 1963). Prior to 1970, very little was known about this species (Taubert and Dadswell 1980). Dadswell (1979) estimated the Saint John River, Canada, population at 18,000 individuals, which may be the largest remaining shortnose sturgeon population.

Shortnose sturgeon are smaller than Atlantic sturgeon; even though their habits are similar, shortnose have not been exploited historically in a special fishery and have been incidentally caught in the Atlantic sturgeon fishery (Ryder 1890). LeSueur (1818, cited in Ryder 1890) wrote:

> "This species... is nevertheless more sought after, and commands a higher price, than the large common species, which attains to the length of about 10 feet. The *A. brevirostrum* and its varieties are brought to the Philadelphia market in the vernal season and fetch from 25 to 75 cents apiece. They are eaten by the common people only."

Ryder (1890) reported shortnose sturgeon were not eaten at all by Delaware fishermen at the time (1888).

At present, shortnose sturgeon have only an incidental commercial importance due to their small size and low availability. It is possible that this species, as well as Atlantic sturgeon, is still taken infrequently in drift gill nets set for American shad in east coast U.S. rivers (Scott and Crossman 1973). Since they are small, commercially unimportant, and destructive to nets, shortnose probably are destroyed upon capture. Commercial fishermen at Long Reach, Saint John River, catch Atlantic and shortnose sturgeons in approximately equal numbers and market them in New York City (Scott and Crossman 1973).



SHORTNOSE STURGEON (Acipenser brevirostrum)

Little is known about the biology of shortnose sturgeon; consequently, effective conservation measures have been difficult to design (McCleave et al. 1977). Most published information concerns studies on northern populations, which have been summarized in this section. Hoff (1979) presented an annotated bibliography on shortnose sturgeon.

3.5.1.1 North Carolina

Historically, the shortnose sturgeon was always considered rare, or went unrecognized by fishermen, and now is believed to be extinct in North Carolina (Schwartz and Link 1976). Michael W. Street of the North Carolina Division of Marine Fisheries believes shortnose sturgeon may have been extirpated in North Carolina waters during the early 1900s, and occasional published accounts of shortnose catches by himself and others were probably misidentified (M.W. Street 1981, pers. comm.). Changes in estuarine habitats probably influenced the demise of shortnose sturgeon in North Carolina waters (Schwartz and Link 1976).

3.5.1.2 South Carolina

Currently the shortnose sturgeon is protected under the Endangered Species Act making it illegal to fish commercially or recreationally for this species. During a survey for Atlantic sturgeon (AFS-9), Smith (1979) reported the capture of 26 shortnose sturgeon and suggested that the species may be more abundant in South Carolina waters than was thought previously. The 1962 Code of Laws of South Carolina, Article 9, stated

> "28-884. OPEN SEASON FOR CATCHING SHORT-NOSE STURGEON -- It shall be lawful for the citizens of this State to catch in the waters of this State and to buy, sell or ship short-nose sturgeon (_Acipenser brevirostris_) between the first day of May and the first day of July each year. But no such short-nose sturgeon shall be caught at a distance of more than 15 miles from the mouth of any river emptying into any bay, gulf or ocean on the border of this State...'

(Leland 1968).

3.5.1.3 Georgia

No information available.

3.5.1.4 Florida

The shortnose sturgeon was incorporated into Florida's fauna list by Evermann and Bean (1898). The original record was considered erroneous for many years until 1949 when a shortnose sturgeon was collected in a commercial haul seine in Big Lake George, Putnam County, on 11 May (McLane 1955). This specimen was donated to the University of Florida by Dr. McLane and catalogued as specimen UF-5714 (Kilby et al. 1959).

3.5.2 Distribution

3.5.2.1 Range

Shortnose sturgeon are restricted to the eastern seaboard of North America from the Saint John River in New Brunswick, Canada, to the St. Johns River, Florida (Scott and Crossman 1973). Records of shortnose sturgeon in the St. Lawrence River were erroneous and based on descriptions of *Acipenser oxyrhynchus* and *A. fulvescens* (Scott and Crossman 1973).

3.5.2.2 Eggs

Shortnose sturgeon eggs are adhesive and demersal.

3.5.2.3 Larvae

Very few young larvae have been collected and so little is known of their distributions.

3.5.2.4 Juveniles

Juvenile shortnose are rarely observed and little is known of their distributions in southeastern river systems.

3.5.2.5 Adults

Adults are observed most often in large tidal rivers but are also taken in brackish and salt water. Captures in the Gulf of Maine indicate this species enters the ocean and travels some distance from natal streams but probably is not so strongly migratory as other species (Scott and Crossman 1973).

3.5.3 Reproduction

3.5.3.1 Maturity

Ryder (1890) reported shortnose sturgeon never reach a size large enough to be captured in gill nets used to fish for Atlantic sturgeon, and sexual maturity is reached much earlier than Atlantic sturgeon. Sexual maturity is achieved by males at approximately 508 mm TL and females at approximately 610 mm and three to five pounds (Scott and Crossman 1973). Populations in the U.S. are capable of spawning more than once but Canadian fish may not possess this capability unless they reach maturity at a smaller size than populations further south (Scott and Crossman 1973). Saint John River sturgeon mature between 10 and 20 years of age (50 to 80 cm FL); mean age to maturity (50% of the population) is 12.4 years for males and 17.2 years for females (Dadswell 1979). Males spawn at two-year intervals and females at three- to five-year intervals (Dadswell 1979).

3.5.3.2 Mating

Mating behavior has not been observed.

3.5.3.3 Fertilization

Eggs are released in middle reaches of large tidal rivers where they are fertilized (Scott and Crossman 1973).

3.5.3.4 Fecundity

Dadswell (1979) reported fecundity of Saint John River sturgeon ranged from 27,000 to 208,000 eggs per female with a mean of 11,568 per kg body weight. The relationship between fecundity and female body weight was estimated as

$$\log F = 3.92 + 1.14 \log W, \quad r = 0.92$$

where F is eggs in thousands and W is total weight in kg. The slight decline in egg number per kg body weight with increased female weight is common to smaller sturgeon species (Dadswell 1979). Small adult size and relatively large egg size contribute to lower fecundity of shortnose sturgeon compared with other sturgeon (Vladykov and Greeley 1963).

3.5.4 Spawning

3.5.4.1 Season and Location

Adults return to natal streams to spawn during spring from April to early June, depending on location, in the middle reaches of large tidal rivers (Scott and Crossman 1973). Spawning in the Saint John River occurs in freshwater, riverine sections of the upper estuary during May and June (Dadswell 1979). Connecticut River spawning occurs during the first half of May (Taubert 1980). Shortnose spawn near mid-April in the Delaware River (Meehan 1909, Hoff 1965). Specific spawning locations for shortnose sturgeon in southeastern rivers have not been determined.

3.5.4.2 Temperature

Shortnose sturgeon in the Saint John River spawn when water temperature ranges between 10 and 15 C (Dadswell 1979). Connecticut River sturgeon spawn at approximately 12 C (Taubert 1980).

3.5.4.3 Spawning Habitat

Not known; may be similar to that of Atlantic sturgeon.

3.5.4.4 Diel Spawning Patterns

No observations.

3.5.5 Life History - Eggs and Larvae

3.5.5.1 Hatching and Crowth

GROWTH - Descriptions of shortnose sturgeon protolarvae 8.0 to 12.5 mm TL were reported by Taubert and Dadswell (1980) in an attempt to ascertain differences between protolarvae of shortnose and Atlantic sturgeons. Separating mesolarvae of the two species is not difficult since by this stage the shortnose develops its characteristic wide mouth (Taubert and Dadswell 1980). Sturgeon in larval and postlarval stages of development have heads with scutes or armor-plates, covered only by the naked integument (Ryder 1890).

FEEDING - Not known.

METABOLISM - Not known.

3.5.5.2 Hardiness

Nothing is known of the hardiness of shortnose sturgeon eggs and larvae to the following variables: salinity, temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport.

3.5.5.3 Swimming Ability

Not known; may be similar to that of Atlantic sturgeon.

3.5.5.4 Chemical Tolerances

Egg and larval chemical tolerances are not known.

3.5.5.5 Pressure

Pressure effects on eggs and larvae are not known.

3.5.6 Life History - Juveniles

3.5.6.1 Nutrition and Growth

FEEDING - Stomach contents of juveniles from the Saint John River indicate they are random suctorial feeders. Nonfood matter (mud, stones, and wood chips) often comprised up to 90% of stomach contents. Food items were comprised mainly of insects and crustaceans (Dadswell 1979).

GROWTH - Young sturgeon are rarely collected so little is known of their growth rates in Southeast waters. Scott and Crossman (1973) stated the growth rate of shortnose sturgeon in early years is apparently similar to that of Atlantic sturgeon, and part of the size difference after reaching maturity may result from the greater tendency of shortnose to remain longer in rivers where food is less available. Shortnose juveniles assume adult characteristics at about 610 mm TL (Scott and Crossman 1973). The von Bertalanffy growth equation for Saint John River juveniles ages one through nine was estimated as

$$L_t = 65.8(1 - e^{-0.104(t + 1.52)})$$

Dadswell 1979). Weight gain for the first 10 years of life was estimated about 100 g per year (Dadswell 1979).

METABOLISM - Juvenile metabolism is not known.

3.5.6.2 Hardiness

The hardiness of juvenile shortnose sturgeon to the following variables is not known: salinity, temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport.

3.5.6.3 Swimming Ability

Juvenile swimming ability is not known.

3.5.6.4 Chemical Tolerances

Juvenile chemical tolerances are not known.

3.5.6.5 Pressure

Pressure effects on juveniles are not known.

3.5.7 Life History - Adults

3.5.7.1 Longevity

Little information is available on the average life expectancy of shortnose sturgeon in Southeast waters. Its status as an endangered species and similarity in appearance with Atlantic sturgeon have precluded obtaining basic life history information. Prior to 1963, the maximum age was believed to be 15 years (Scott and Crossman 1973). Greatest ages of specimens examined by Dadswell (1979) from the Saint John River estuary were 67 years for females and 32 years for males.

3.5.7.2 Nutrition and Growth

FEEDING - The protusible tube mouth adapts sturgeons to feeding on the bottom. A stray adult sturgeon 794 mm TL was collected in the St. Johns River, Florida, in May 1949; stomach contents were mostly silt and chironomid larvae (McLane 1955). Hudson River shortnose reportedly eat sludgeworms, chironomid larvae, small crustaceans, and plants (Scott and Crossman 1973). Dadswell's (1979) study indicated shortnose fed only during the warmer-water season in freshwater areas (less than 3 $^{o}/oo$) of the Saint John River estuary. Both the incidence of prey and stomach fullness increased sharply in June when water temperatures exceeded 10 C, and feeding dropped by November. In the saline portion of

the estuary (greater than 3 $^{o}/oo$), sturgeon fed heavily in fall, winter, and spring. Ripening males captured in saline water during winter usually had full guts, but ripening females in both saline and freshwater areas were always empty. Saint John River adults fed mainly on molluscs; the freshwater diet was dominated (94%) by small gastropods, while the brackish water diet consisted mainly of small clams (Dadswell 1979).

GROWTH - Shortnose sturgeon grows more slowly and attains a smaller maximum size than other Acipenser species of the North American east coast (Magnin 1964, Vladykov and Greeley 1963). Saint John River sturgeon grow more slowly than most other shortnose sturgeon populations (Hoff 1965) and have one of the slowest reported growth rates for fishes (Beverton and Holt 1959). Slow growth rate is probably a result of the short annual duration of warm water in the Saint John River, resulting in a short maximum feeding period for shortnose (Dadswell 1979). A check zone was present between ages seven and twelve on most pectoral rays examined, indicating change of habitat and diet with onset of maturation. Length increment per year is greatest during early growth and declines after age six; length becomes asymptotic at 120 to 125 cm and age 60 to 70 years. The von Bertalanffy growth equation for adults of both sexes, ages 10 to 67 years, was estimated as

$$L_t = 130(1 - e^{-0.042(t + 1.96)}).$$

The von Bertalanffy length (FL in cm) and weight (kg) relationships for both sexes were estimated as

$$\text{Female} \quad L_t = 127.0(1 - e^{-0.047(t + 1.107)})$$

$$W_t = 24.8(1 - e^{-0.042(t - 0.80)})^3$$

$$\text{Male} \quad L_t = 108.7(1 - e^{-0.063(t - 0.79)})$$

$$W_t = 13.9(1 - e^{-0.063(t - 2.51)})^3$$

Weight gain between 10 and 40 years of life was estimated about 300 g per year and tapers off after 40 years of age. The von Bertalanffy growth equation for weight, all specimens ages 10 to 67 years combined, was estimated as

$$W_t = 23.9(1 - e^{-0.04\text{[illegible]}(t - \text{[illegible]}.06)})^3$$

Mean weight of age classes 25 to 35 years was depressed below the estimated weights predicted from the previous equation, probably due to growth arrest in males and the inclusion of many spent females (Dadswell 1979).

METABOLISM - Adult metabolism is not known.

3.5.7.3 Hardiness

SALINITY - Adults can apparently tolerate salinity changes up to 10 $^{o}/oo$ within a two-hour period with no evidence of stress (McCleave et al. 1977).

TEMPERATURE - Adult hardiness to temperature is not known.

SALINITY-TEMPERATURE INTERACTION - Adult hardiness to this factor is not known.

ACCLIMATION - No information available.

OXYGEN - No information available.

SUSPENDED SEDIMENTS - The highly turbid waters of Montsweag Bay Estuary, Maine, apparently has little effect on the ability of shortnose sturgeon to navigate within the system (McCleave et al. 1977).

pH - Adult hardiness to this variable is not known.

TRANSPORT - No information available.

3.5.7.4 Swimming Ability

Adult shortnose sturgeon exhibited mean swimming speeds of 8.1 to 34.0 cm s^{-1} or 0.07 to 0.37 bl s^{-1} in Montsweag Bay, Maine. There were no diel differences in swimming rates (McCleave et al. 1977).

3.5.7.5 Chemical Tolerances

Chemical tolerances of adults are not known.

3.5.7.6 Pressure

Effects of pressure on adults are not known.

3.5.8 Behavior

3.5.8.1 Juvenile Migration and Local Movement

Nothing is known of the localized distributions and movement patterns of juvenile shortnose sturgeon in Southeast waters. Some information for juveniles from northern populations is presented in the following section (3.5.8.2).

3.5.8.2 Adult Migration and Local Movement

Habits of the shortnose sturgeon are similar to those of the Atlantic sturgeon (Dees 1961).

MONTSWEAG BAY ESTUARY, MAINE - Adult shortnose sturgeon were tracked by ultrasonic telemetry during summer by McCleave et al. (1977). Some sturgeon wandered extensively while others exhibited strongly-oriented movements in the large, shallow bay. Shortnose often moved through waters less than one to two m deep, were not oriented by channels bisecting the bay, and at times crossed channels without following bottom contours. There were no diel differences in swimming speeds or straightness of movement. Movement patterns indicated sturgeon were well-oriented to tidal currents, moving with or against the tide. Shortnose moved freely through waters of widely varying salinities, and sometimes encountered salinity changes of 10 $^{o}/oo$ in less than two hours (McCleave et al. 1977).

SAINT JOHN RIVER ESTUARY, NEW BRUNSWICK, CANADA - Seasonal movements of shortnose sturgeon in the estuary were determined by Dadswell (1979). Patterns were complex due to overlapping behavior patterns of various age groups and spawning condition. Abundance of shortnose in channels and over foraging grounds in the lower estuary increased in late spring, decreased in mid-summer, then increased again in early fall. Abundance on foraging grounds in the upper estuary increased until August, then declined. Average midsummer abundance on foraging grounds was highest in mid-estuary, where salinities averaged approximately 1 $^{o}/oo$. During summers of high river flow, summer abundance was displaced seaward. Reduced river flow conditions caused summer abundance to shift upriver. Recapture data suggest shortnose summer abundance patterns represent annual migration upriver in spring-summer and downriver in fall by the majority of the non-ripening portion of the population.

Mean minimum rate of upstream movement was estimated at four km per day between June and August 1975. Late summer migration downstream was probably in response to seasonal cooling of water temperatures. Emigration was much more rapid than upriver migration; by late September, summer foraging grounds were nearly empty and the shortnose population was concentrated in discrete overwintering sites. Saint John River sturgeon overwinter in estuarine lakes, deep saline regions of the lower estuary, and the Bay of Fundy. Lake sites were characterized by depths in excess of 10 m, moderate tidal currents, and cold water (0 to 2 C) and were occupied primarily by juveniles and ripening (Stage IV) females. Sturgeon in freshwater overwintering sites seldom contained food items. Lower estuary sites were typlified by salinities averaging 20 $^{o}/oo$ and temperatures 2 to 13 C, and were frequented primarily by nonripening adults, stage IV males, and large juveniles. All fish except ripening females were feeding. Tag return data also indicated a portion of the population overwinters in the Bay of Fundy. Recapture data also indicated that shortnose sturgeon may pair bond, a phenomenon unreported for sturgeon. Juvenile shortnose sturgeon (less than 45 cm) appear to be riverine and remain nonmigratory until eight years of age (45 cm) (Dadswell 1979).

3.5.8.3 Responses to Stimuli

VISION - McCleave et al. (1977) suggested shortnose sturgeon are not visually oriented in their movements. Sturgeon tracked in Montsweag Bay, Maine, during summer did not exhibit movements correlated with sun or moon position, and no diel activity rhythm was apparent. In addition, several shortnose had milky eyes and appeared blind, but exhibited the same behavior as the others (McCLeave et al. 1977).

COMPETITION - The seasonal occurrence of shortnose sturgeon in the Saint John River estuary during summer may be influenced by competition with Atlantic sturgeon. In salinities greater than 3 $^{o}/oo$, Atlantic sturgeon outnumbered shortnose sturgeon 10 to 1 except during fall migration of shortnose to saline waters. In freshwater, the numerical abundance was reversed (Dadswell 1979).

3.5.9 Population

3.5.9.1 Sex Ratio

There is no external method of sexing a sturgeon unless the fish is near spawning condition; fish must be sacrificed to determine sex (Dees 1961).

SAINT JOHN RIVER, NEW BRUNSWICK - Dadswell (1979) determined the overall sex ratio of the shortnose population to be 2:1 in favor of females. At younger ages the ratio was 1:1 but for adults over 20 years of age the population was dominated by females, an indication of the shorter life span for males.

3.5.9.2 Age Composition

No information available.

3.5.9.3 Size Composition

No information available.

3.5.9.4 Abundance and Population Status

The Saint John River population was estimated by Dadswell (1979) to contain between 6,200 and 18,500 individuals and is probably one of the largest single populations of this species on the east coast of North America. Commercial landings reported for Atlantic sturgeon in Southeast States may include some shortnose sturgeon up to the mid-1950s. Shortnose sturgeon were probably extirpated in North Carolina just after the turn of the century (M.W. Street 1981, pers. comm.) and may be more abundant in South Carolina than was thought previously (Smith 1979). Questionnaire responses by marine and freshwater representatives indicated most shortnose populations are no longer present or threatened in Southeast United States waters (Table 3.5-1). Probable reasons for the decline (Table 3.5-2) were believed to be related to habitat alteration.

3.5.9.5 Factors Affecting Reproduction and Recruitment

Shortnose sturgeon apparently do not spawn every year but participate in the annual spawning run regardless of condition. Males in the Saint John River spawn in two-year intervals and females spawn every three to five years (Dadswell 1979). Juveniles apparently remain riverine until age eight when they emigrate from the system. Age to maturity averages 12.7 years for males and age 18 for females in the Saint John River. All these factors contribute to low recruitment to the spawning

Table 3.5-1. Status of shortnose sturgeon, *Acipenser brevirostrum*, in river systems within Region 4 based on questionnaire responses to question VI-2. S = response from marine representative; F = response from freshwater representative.

RIVER SYSTEM	STATUS
NORTH CAROLINA	
Currituck Sound	No longer present (S)
Albemarle Sound	No longer present (S), Threatened (F)
North R.	No longer present (S)
Pasquotank R.	No longer present (S)
Little R.	No longer present (S)
Perquimans R.	No longer present (S)
Yeopim R.	No longer present (S)
Chowan R.	No longer present (S), Threatened (F)
Meherrin R.	No longer present (S)
Roanoke R.	No longer present (S), Threatened (F)
Cashie R.	No longer present (S)
Scuppernong R.	No longer present (S)
Alligator R.	No longer present (S)
Pungo R.	No longer present (S)
Pamlico R.	No longer present (S)
Tar R.	No longer present (S), Threatened (F)
Neuse R.	No longer present (S), Threatened (F)
Trent R.	No longer present (S)
North R.	No longer present (S)
Newport R.	No longer present (S)
White Oak R.	No longer present (S)
New R.	No longer present (S)
Cape Fear R.	No longer present (S), Threatened (F)
Northeast Cape Fear R.	No longer present (S), Threatened (F)
Black R.	No longer present (S)
Pee Dee R.	Threatened (F)
SOUTH CAROLINA	
Waccamaw R.	Not known (F), Threatened (S)
Little Pee Dee R.	Threatened (S)
Great Pee Dee R.	Not known (S), Threatened (F)
Black R.	Not known (S), Threatened (F)
Santee R.	Not known (S), Threatened (F)
Cooper R.	Not known (S), Threatened (F)
Ashley R.	Not known (S), Threatened (F)
Edisto R.	Not known (S), Threatened (F)
Ashepoo R.	Not known (S), Threatened (F)
Combahee R.	Not known (S), Threatened (F)
Sampit R.	Not known (S), Threatened (F)
Salkchatchie R.	Threatened (F)
Savannah R.	Not known (S), Threatened (F)
Lynches R.	Threatened (F)

Table 3.5-1. Shortnose sturgeon (cont'd.).

RIVER SYSTEM	STATUS
GEORGIA	
Savannah R.	Threatened (SF)
Ogeechee R.	Threatened (SF)
Altamaha R.	Threatened (SF)
Oconee R.	Threatened (F)
Satilla R.	Threatened (SF)
Ocmulgee R.	Threatened (F)
St. Marys R.	Threatened (SF)
Chattahoochee R.	Probably never present (F)
Flint R.	Probably never present (F)
FLORIDA	
St. Marys R.	Not known (F)
Nassau R.	Not known (F)
St. Johns R.	Threatened (F)
Pellicer Cr.	
Moultrie Cr.	
Tomoka R.	
Hillsborough R.	Probably never present (S)
Suwannee R.	Probably never present (S)
Apalachicola R.	Probably never present (S), Not known (F)
Ockockonee R.	Not known (F)
Escambia R.	
ALABAMA	
Alabama R.	Not known (S)
Tombigbee R.	Not known (S)
Perdido R.	Not known (S)
Bon Secour R.	Not known (S)
Fish R.	Not known (S)
Magnolia R.	Not known (S)
Dog R.	Not known (S)
Fowl R.	Not known (S)
Tennessee R.	
Chattahoochee R.	
Coosa R.	
Tallapoosa R.	

Table 3.5-2. Factors possibly important or very important to the decline of certain populations of shortnose sturgeon, *Acipenser brevirostrum*, within Region 4 based on questionnaire responses to question I. S = response from marine representative; F = response from freshwater representative; C = reponse from other agencies.

NORTH CAROLINA

Dams and impoundments (C)
Industrial water intakes (C)
Location of industrial discharges (C)
Sewerage outfalls (C)
Inadequate control of water release from dams (C)
Spawning areas too accessible to fishermen (C)

SOUTH CAROLINA

Dams and impoundments (S)
Inadequate fishway facilities (S)
Reduction in spawning habitat (S)
Spawning areas too accessible to fishermen (S)
Poor water quality (S)

GEORGIA

Channelization (S)
Dredge and fill projects (S)
Dams and impoundments (S)
Location of industrial discharges (S)
Chemical pollution (S)
Thermal effluents (S)
Reduction in spawning habitat (S)
Reduction in nursery areas (S)
Poor food availability (S)
Spawning areas too accessible to fishermen (S)
Poor water quality (S)

FLORIDA

Inadequate information

ALABAMA

Dams and impoundments (S)
Location of industrial discharges (S)
Road construction (S)
Sewerage outfalls (S)
Inadequate fishway facilities (S)
Poor food availability (S)
Poor water quality (S)
Low oxygen levels (S)

population and limited reproductive potential, life history aspects conducive to easy overexploitation of stocks.

3.5.9.6 Mortality

Total instantaneous mortality rate (Z) for Saint John River shortnose sturgeon were estimated as 0.12 for 1974 and 0.15 for 1975. No directed commercial exploitation exists for shortnose in the Saint John River, but considerable numbers are taken incidentally in the salmon, shad, striped bass, and alewife fisheries (Meth 1973). Dadswell (1979) observed a considerable portion of sturgeon captured is returned unharmed but there is fishing mortality for shortnose sturgeon in Southeast waters could be located.

3.5.10 Predator-Prey Relationships

Nothing is known of the predators of larger shortnose sturgeon. Even the young may be adequately protected from predation by their armored plates. Young and adults both compete with other bottom-feeding fishes such as suckers (Scott and Crossman 1973).

3.5.11 Diseases

Parasites of shortnose sturgeon were reported by Appy and Dadswell (1978). Eleven species of helminth and arthropod parasites infect both shortnose and Atlantic sturgeons in the Saint John River, NB., Canada, and are host specific. Areas of infestation include the gills, mesenteric blood vessels, spiral valve, gizzard, and external areas (Appy and Dadswell 1978).

3.5.12 Exploitation

Shortnose sturgeon are presently protected by the Endangered Species Act and no commercial or recreational exploitation is allowed. Some shortnose may be incidentally taken by other fisheries, particularly for shad and Atlantic sturgeon.

3.5.13 Protection and Management

No information could be obtained concerning present management activities or proposed protection for shortnose sturgeon by any State or Federal agencies.

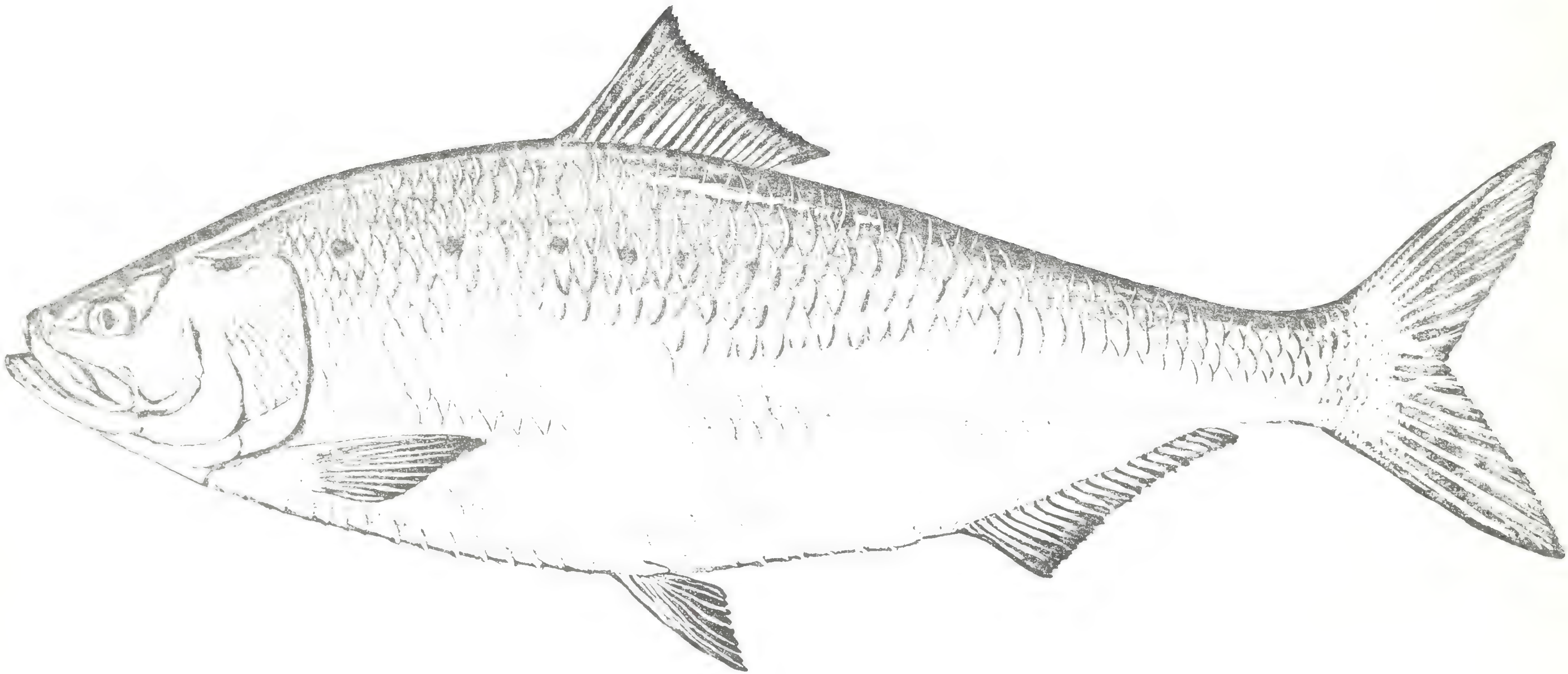
3.6 American Shad (*Alosa sapidissima*)

3.6.1 Historical Significance

American shad are the largest members of the herring family, Clupeidae, in the United States. Other common names are white shad, roe shad, or shad. Prior to World War II this species was the most valuable food fish on the Atlantic coast. Shad were first utilized as a food source by Indians, and by the mid-1700s a profitable shad fishery developed from Maine to Chesapeake Bay. American shad fisheries as far south as Florida became important by the early 1800s as water and rail routes were developed, which provided easy access to northern markets. By 1920, the value of shad in Chesapeake Bay was more than the combined value of alewives, croakers, weakfish, and striped bass--although it ranked third in the number of pounds landed (Hildebrand and Schroeder 1928).

The full economic important of the American shad fishery was realized in the 1800s and resulted in fish culture and stocking programs by State and Federal agencies. Attempts to culture shad were not successful until 1867. The United States Fish Commission began hatching shad on the Connecticut River at Hadley Falls, Massachusetts, in 1872. The following year, the Commission successfully hatched 95,000 shad fry on the Potomac River at Washington, D.C., which was the beginning of shad-hatching operations in the Chesapeake drainage. By 1875, the State of Maryland began a program, with Virginia and North Carolina following suit several years later, but most effort remained with the Federal Government (Hildebrand and Schroeder 1928). Stocking programs were initiated along the Atlantic coast, but culturists were unable to successfully handle fingerlings two to five inches in length. Stocking typically was accomplished by removing dam boards and forcing shad to swim out with the receding water when tidal or flood water backed up to a rearing pond. In 1871, American shad fry were successfully transported by rail to the west coast and introduced in the Sacramento River, California. Pacific coast stocking also occurred in 1885 and 1886 in the Columbia, Snake, and Willamette Rivers (Parks 1978). From these stockings, shad now range from Baja California to Kodiak Island, Alaska (Hart 1973). Attempts to stock American shad in tributaries of the Mississippi River and streams of peninsular Florida were unsuccessful (Cheek 1968).

From 1896 to 1960, the Atlantic coast shad fishery changed little except for magnitude in yield. Gear types remained relatively unchanged, but techniques were improved



American shad

Alosa sapidissima

to achieve economy. Shad landings peaked at greater than 50 million pounds in 1896. New Jersey was first in production with 14 million pounds followed by Virginia with 11 million pounds. By 1960, however, estimated total shad catch was only slightly more than eight million pounds. Maryland led production with about 1.5 million pounds, followed by Virginia (1.4 million) and North Carolina (1.3 million).

The dramatic decline in the American shad fishery along the Atlantic coast is best reflected by the fishery in the Delaware River Basin as reviewed by Chittenden (1974). Annual commercial landings in the Basin from 1890 to 1901 ranged from 11 to 17 million pounds and were several times greater than in any other river system. Shad abundance declined rapidly after 1901 with the exception of a resurgence in 1907. This may have indicated that, by 1903, pollution was affecting the successful seaward movement of young shad from the Delaware River. By 1920, less than 0.5 million pounds were landed and abundance has remained low since then (Chittenden 1974). By 1957, the Delaware River shad fishery was economically unfeasible to operate (Sykes and Lehman 1957).

In 1950, the U.S. Fish and Wildlife Service began a study of the Delaware River shad population to gather information for the Atlantic States Marine Fisheries Commission that might be useful in rehabilitating shad runs of the Atlantic coast. Even up to 1976, however, commercial catches of shad on the Atlantic coast continued to decline steadily from 7.5 million pounds to less than two million pounds. Some coastal areas have shad runs considered nearly extinct. Therefore, shad populations may be reaching a level that will be difficult to increase without a large, coordinated restoration program (St. Pierre 1977). The substantial declines in shad abundance have been mainly attributed to dam construction, pollution, and overfishing.

3.6.1.1 North Carolina

During the latter 1800s, the shad fishery of North Carolina steadily increased until the turn of the century and at one time exceeded that of any other state (Smith 1907). In 1896, the Neuse River was regarded as the most important shad stream between the St. Johns River, Florida, and the James River, Virginia (Walburg and Nichols 1967). Maximum shad production was reached in 1896 and 1897, and other years of maximum production were from 1900 to 1902 (Smith 1907). After this period, reports Smith, excessive fishing caused a

decline in shad populations and the welfare of the fishery became seriously threatened. Principal cause of the decline was attributed to the catching of disproportionately large quantities of shad in or near saltwater, with a resulting decrease in the supply of fish on the spawning grounds. This matter received special attention in the North Carolina Legislature in 1904, and a law designed to afford greater shad protection was enacted and became effective in 1905 (Smith 1907). In spite of the serious decline in the Neuse River shad fishery, the landings in Pamlico, Carteret, and Chowan Counties (which includes the Neuse River commercial fishery) represented from two to 42% of the total shad landed in North Carolina during the period 1889 to 1968 (Chestnut and Davis 1975). Since 1960, these three counties produced an average of 27% of the total North Carolina shad production (Hawkins 1979). Drift-netting for American shad has been a socially significant activity on the Neuse, with large crowds gathering to catch fish and eat (Hawkins 1979).

Other major shad-producing rivers in North Carolina are the Tar-Pamlico, Cape Fear, Northeast Cape Fear, and Chowan (Marshall 1977, Hawkins 1979). Commercial fishermen indicate that significant anadromous populations once existed in the New River, but now it appears that these stocks are low in numbers, probably due to channelization and development (Sholar 1975). Shad landings in the Cape Fear River were 42,000 pounds in 1978 and 52,000 pounds in 1979. Prices for roe shad (females) were $5.00 per fish and bucks (males) sold for $3.00 per fish in March 1980, but April prices dropped as catches increased (Fischer 1980).

Smith (1907) summarized early shad culture in North Carolina. North Carolina was one of the first states to take up the artificial propagation of shad, but soon abandoned all work of the kind and for many years demands for fish culture in that State were met by the Federal Government. In 1873, under the direction of U.S. Fish Commissioner Baird, about 45,000 shad were hatched at New Bern and planted in local waters. Shad-hatching efforts at New Bern in 1875 were unsuccessful. In 1877, North Carolina began fish culture operations on its own behalf with a shad hatching operation on the Neuse River that met with little success. Hatching in 1878 was noteworthy as a joint effort by the U.S. Fish Commission, Virginia, Maryland, and North Carolina. The operation

was located on Salmon Creek at the head of Albemarle Sound, and production was "a number of million fry." Shad hatching was continued by the Federal Government in 1879 at the mouth of the Chowan River with a steamer--Lookout--being employed in the work. In 1880, the State constructed a shad hatchery at Avoca and utilized the eggs furnished by the Capehart Seine Fisheries at Sutton Beach and Scotch Hall. This operation proved quite successful. In 1881, the steamer Fish-Hawk was first employed as a floating hatchery--suppled by the Federal Government--and was utilized until the turn of the century for shad hatching in Albemarle Sound. The State continued to operate the Avoca Hatchery until 1884. In 1882, the McDonald hatching jar was adopted at the hatchery, thus making North Carolina the first state to employ the device. In 1885, North Carolina discontinued all fish culture work with responsibility retained by the Federal Government (Smith 1907).

3.6.1.2 South Carolina

The American shad fishery in South Carolina became commercially important during the latter part of the nineteenth century when railroad and water route extensions provided easy access to northern markets (Walburg and Nichols 1967). By 1880, an extensive gill net fishery had developed which utilized an estimated 100,000 yards of drift and stake nets to catch 208,000 pounds of shad. By 1896, the shad catch had increased to 672,000 pounds (Crochet et al. 1977). At that time it became apparent that natural reproduction was no longer sustaining South Carolina shad populations. Hatching and stocking programs were initiated in an attempt to replenish declining stocks (Stevenson 1899, cited in Ulrich et al. 1979). Evidently, an overfishing problem had been recognized as early as 1869 and some runs were in danger of depletion, even though harvest was still increasing (Cable 1944, cited in Crochet et al. 1977). Despite these intensive stocking efforts, which were terminated in 1938, South Carolina shad stocks declined steadily (D.M. Cupka 1981, pers. comm.).

All major river systems in South Carolina support commercial shad fisheries. The Winyah Bay system, formed by the confluence of the Waccamaw, Pee Dee, and Sampit Rivers, is the principal shad-producing area in the State. From 1960 to 1978, the shad fishery on the Pee Dee and its tributaries was basically the same,

except for the absence of a shad fishery in Little Pee Dee River in 1978 (Ulrich et al. 1979). The Sampit River supported a small shad fishery in 1896 but none was recorded until recently, perhaps due to improved water quality resulting from pollution control along the river (Ulrich et al. 1979). The Santee River also supported a substantial commercial shad fishery, concentrated near Jamestown, in 1978. The Edisto River shad fishery is regulated by a registered set net program and designated drift area (Ulrich et al. 1979). Combahee River also sustained a significant shad fishery in 1978. The Ashepoo River was closed for a 10-year period beginning in 1936; shad catches were good after the season reopened (Mansueti and Kolb 1953, cited in Ulrich et al. 1979). Historically, the Savannah River shad fishery has been located in the lower river. A dam at Augusta, Georgia, has prevented shad from moving to upstream spawning areas, and pollution from sewage and pulp and paper effluents have limited shad populations to the lower river since the 1950s (Mansueti and Kolb 1953, cited in Ulrich et al. 1979).

3.6.1.3 Georgia

The following description of Georgia's shad fishery has been quoted from Michaels (1980): "American shad, *Alosa sapidissima*, is a valuable commercial fishery resource in several of Georgia's coastal streams. It comprises one of the largest finfish landings in the State. The Altamaha River fishery is by far the largest in Georgia. Walburg and Nichols (1967) reported that shad landings from this river accounted for only 20% of Georgia's shad catch in 1896 but had increased to 67% of the total for the State by 1960. Godwin and McBay (1967) showed that in 1967 the Altamaha River fishery contributed 69% of Georgia's total shad harvest.

"Georgia's shad fisheries have followed the same general trend as those of other Atlantic Coast States. Commercial landings of American shad peaked in 1908 at 1,333,000 pounds. The fishery declined drastically after that date and reached a low of 75,000 pounds in 1939, valued at $15,000. Since then the catch has fluctuated greatly. The reported catch in 1980 was 203,698 pounds valued at $192,348 (Jim Music, personal communication, 5 December 1980, GA Dept. of Nat. Res., Coastal Res. Div., Brunswick, GA). The average annual decrease in the catch has been about 37,000 pounds since 1969.

"It is not known whether pollution, dam construction, and/or overfishing have been the major causes in the decline of Georgia's shad fisheries. For example, the Ogeechee River was once rated as the most important shad stream in Georgia (Mansueti and Kolb 1953, cited by Ulrich et al. 1979). By the early 1950s there was evidence of siltation and pollution. Sykes (1956) estimated escapement of the 1954 shad spawning stock at 34%, a possible indicator of overfishing. Although no dams were constructed anywhere along its length, the Ogeechee River now contributes only 12% of the total shad catch for Georgia.

"The Altamaha River, Georgia's largest shad fishery, has not had a serious problem with pollution. There is a chemical cellulose plant at river mile 50 and a source of domestic waste at river mile 10 (Adams 1970). Dams are located only on the two major tributaries, the Oconee and Ocmulgee Rivers. Godwin (1968) showed a 56.7% escapement rate for American shad, higher than in most other Atlantic coast shad streams. Although he concluded that overfishing was not a problem in 1968, the shad catch began to drop significantly two years later and has not returned to its 1968 peak."

3.6.1.4 Florida

American shad in Florida have been commercially important since the mid-1800s and retain that significance today. Shad are common to the St. Marys and St. Johns Rivers and probably once occurred as far south as Tomoka River north of Cape Canaveral (Williams and Grey 1975).

The St. Johns River system currently supports a commercial shad fishery which has operated since the mid-1800s (Williams and Bruger 1972). Shad are caught by gill nets and haul seines and most are iced and shipped whole to northern markets; very few are sold to Florida consumers (Williams et al. 1975). In the past 30 years, the American shad has become a prized sportfish in many Florida rivers, particularly the St. Johns River (Williams et al. 1975).

Production of both commercial and sport shad fisheries is declining and proposed changes in the upper St. Johns River further threaten the shad population

(Williams and Bruger 1972). St. Johns River shad have been studied by the U.S. Fish and Wildlife Service, the State of Florida, and McGill University (Canada). These studies have developed baseline information to aid in formulating a sound management program for American shad in Florida.

3.6.2 Distribution

3.6.2.1 Range

On the Atlantic coast, American shad range from the St. Johns River, Florida, to the St. Lawrence River, Canada, and occur in greatest abundance from North Carolina to Connecticut (Walburg and Nichols 1967). Shad probably occur as far south as Tomoka River, Florida, a small freshwater tributary of Halifax River (a brackish coastal lagoon)(Williams and Grey 1975). Records south of Cape Canaveral are scarce, but rare catches occur in the Sebastian, Ft. Pierce, and St. Lucie Inlets (Williams and Grey 1975).

3.6.2.2 Eggs

Shad eggs are non-adhesive and slightly heavier than water, so they sink to the bottom where they are carried along by currents (Ulrich et al. 1979).

3.6.2.3 Larvae

Larval shad are most abundant at the surface (Marcy and Jacobson 1976), and generally drift downstream and disperse throughout the system after reaching a sufficient size (Godwin and Adams 1969).

3.6.2.4 Juveniles

Juvenile shad form schools at 20 to 30 mm TL and prefer deep pools well away from shorelines in non-tidal areas, although they may occasionally occur in shallow riffles (Chittenden 1969). Juveniles leave freshwater in autumn and generally remain in the ocean for three to five years before returning to their natal streams to spawn (Neves and Depres 1979).

3.6.2.5 Adults

Discrete spawning populations exist in river systems along the Atlantic coast (Hollis 1948; Hill 1959; Nichols 1960, 1966b; Carscadden and Leggett 1975a).

Shad from U.S. rivers congregate with those from Canadian rivers in the Gulf of Maine during summer and move south to possibly overwinter off Middle and South Atlantic States; in the spring adults move north or south toward natal rivers to spawn (Neves and Dupres 1979).

3.6.3 Reproduction

3.6.3.1 Maturity

Most shad mature at three to six years of age. Age at maturity increases with increased latitude (Carscadden 1975). Males usually enter natal rivers for the first time at age class IV and females at age V.

3.6.3.2 Mating

No information available.

3.6.3.3 Fertilization

Eggs are released in open water of rivers where they are fertilized (Cheek 1968).

3.6.3.4 Fecundity

Fecundity ranges from 100,000 to 600,000 eggs depending on the length, weight, and age of the fish as well as the river of origin (Cheek 1968). Shad fecundity apparently decreases with increasing latitude (Carscadden 1975).

Hudson River shad, ages III through IX, produced 116,000 to 468,000 eggs per female (Lehman 1953). During the period 1953 to 1959, York River shad contained 169,000 to 436,000 eggs per female (Nichols and Massmann 1962). Shad stock from the St. Johns River produced 277,000 to 659,000 eggs per female from 1953 to 1958 (Walburg 1960a).

Fecundity of shad (ages V-IX) offshore North Carolina ranged from 197,323 to 457,530 with a mean of 281,137

FECUNDITY - FORK LENGTH:

$$F = 1.58 \times 10^4 \quad F - 4.57 \times 10^5$$

FECUNDITY - WEIGHT:

$$F = 1.13 \times 10^5 \quad W + 7.34 \times 10^4$$

FECUNDITY - AGE:

$$F = 1.74 \times 10^4 \quad A + 1.73 \times 10^5$$

(Holland and Yelverton 1973).

Table 3.6-1. Spawning season of American shad.

RIVER SYSTEM	SPAWNING SEASON	SOURCE(S)
Delaware River	Late May into July within a 3 week period, ending progressively later proceeding upstream	Chittenden (1976a)
Roanoke River	April	Johnson et al. (1978)
Neuse River	Early April to late May	Hawkins (1979)
White Oak River	April and May	Sholar (1975)
Cape Fear River	Early April to late May	Fischer (1980)
Waccamaw-Pee Dee system	Run from January to April Peak activity in April	Ulrich et al. (1979) Crochet et al. (1977)
Altamaha River	Mid-March to late May	Godwin and Adams (1969)
St. Johns River	Late February to mid-April	Walburg (1960b)

Table 3.6-2. Location of spawning grounds of American shad.

RIVER SYSTEM	LOCATION	SOURCE(S)
Delaware River	Freshwater of main river extending into the East and West branches. No spawning in grossly polluted tidal water	Chittenden (1976a)
Roanoke River	Conine Creek downstream from U.S. Hwy. 17 to U.S. Hwy 258 bridge. Greatest concentration at Conoho Creek downstream from N.C. Hwy 125	Johnson et al. (1978)
Neuse River system	Neuse - Usually upstream from Trenton. From U.S. Hwy 70 Business (RM 85) in Kinston to S.R. 1224 bridge upstream from Goldsboro (RM 145), upstream from the Quaker Neck Dam	Marshall (1977) Hawkins (1979)
	Contentnea Creek - S.R. 1225 bridge to creek mouth	Hawkins (1979)
	Little River - N.C. Hwy 581 bridge to river mouth	Hawkins (1979)
	Trent River - from mouth to a point near Pleasant Hill	Baker (1968)
White Oak River	In the Martin Marietta Belgrade Quarry Lakes	Sholar (1975)
Cape Fear River	Downstream from Wilmington to Lock and Dam No. 1 and possibly the area downstream from Lock and Dam No. 2	Fischer (1980)
Pee Dee River	Between RM 40 and RM 100	Crochet et al. (1977)
	Also the Piedmont section in North Carolina below Blewett Falls Dam	Baker (1968)
Altamaha River	RM 60 to RM 120	Godwin and Adams (1969)

Table 3.6-2. Spawning grounds (cont'd.).

RIVER SYSTEM	LOCATION	SOURCE(S)
St. Johns River system	Crow's Bluff west of Deland south about 100 miles to U.S. Hwy 192 west of Melbourne. Greatest concentration occurred between Lake Monroe and Lake Poinsett. Importance of this area increased during low water when there was little current in the area north of Lake Harney	Williams and Bruger (1972)
	Econlockhatchee River and Black Creek	Williams et al. (1975)

3.6.4 Spawning

3.6.4.1 Season and Location

Spawning runs occur in a south to north temporal progression (Table 3.6-1, Table 3.6-2) beginning as early as December in Florida and as late as June in Canada (Walburg 1960b).

3.6.4.2 Temperature

Shad spawning occurs between 12 to 20 C with eggs taken in abundance at 12 C, although a few may be collected at lower temperatures (Ulrich et al. 1979). Median spawning temperature is 16 to 17 C (Massman 1951, Pacheco 1968). Spawning temperatures in specific river systems are:

Neuse - 15 to 24 C (Hawkins 1979).
Trent - 16 C (Marshall 1977).
Altamaha - 19.6 to 22 C (Godwin and Adams 1969).
St. Johns - 21.1 to 25.5 C (Cheek 1966).

3.6.4.3 Spawning Habitat

Shad prefer tidal freshwater with extensive flats or over sandy or pebbly shallows near creek mouths (Pacheco 1968). Spawning also occurs in deep channels adjacent to shoals (Massman 1951). Physical characteristics such as current, depth, bottom type, and bottom contour determine the spawning locations in the St. Johns River (Table 3.6-3); chemical characteristics are adequate in all areas and apparently do not contribute to habitat selection (Williams and Bruger 1972). Waters range from clear to turbid in velocities 0.3 to 0.9 m s^{-1} and depths 0.9 to 12.2 m (Walburg and Nichols 1967).

3.6.4.4 Diel Spawning Patterns

Spawning probably occurs at night in clear water, beginning later in the day. In turbid waters it may occur all day (Chittenden 1976a). Most spawning activity occurs in late afternoon and evening, continuing until midnight (Ulrich et al. 1979).

Table 3.6-3. Description of American shad spawning habitat.

RIVER SYSTEM	HABITAT	SOURCE(S)
Delaware River	Shallow riffle areas in preference to pool habitats	Chittenden (1976a)
Virginia	Fresh tidal waters primarily in mainstreams	Davis (1973)
Neuse River	Limited primarily to the main section	Hawkins (1979)
St. Johns River	Clean sand bottom less than 4 m deep in a current of 30 to 46 cm s^{-1}	Williams and Bruger (1972)

3.6.5 Life History - Eggs and Larvae

3.6.5.1 Hatching and Growth

HATCHING - Hatching depends on water temperature and is limited to a range of 12 to 19 C (Leach 1925a). Optimum conditions for laboratory development occurs at a temperature of 17 C, 7.5 $^{o}/oo$, and darkness with hatch occurring in three to eight days (Leim 1924). Maximum hatch and survival of eggs and larvae occurs within the range 15.5 to 26.6 C (Leggett and Whitney 1972). Temperatures of 20.0 to 23.4 C produced hatching in three to five days but resulted in extensive larval abnormalities, while temperatures of 7 to 9 C were usually lethal (Leim 1924).

GROWTH - Newly-hatched larvae are 9 to 10 mm long and absorb the yolk in four to five days. Duration of the larval stage is 21 to 28 days (Ryder 1887). Larvae become juveniles at 25 to 28 mm TL (Leim 1924).

FEEDING - Larval shad in the Connecticut River above Holyoke Dam, Massachusetts, consumed aquatic crustaceans and tendipedid larvae and pupae (Levesque and Reed 1972).

3.6.5.2 Hardiness

SALINITY - No information available.

TEMPERATURE - Fertilized American shad eggs subjected to time-excess temperatures of 6 to 10 C above ambient for 2.5 to 60 minutes (cooling time 60 to 300 minutes) did not exhibit a significant decrease in hatching success (Schubel 1974).

SALINITY-TEMPERATURE INTERACTIONS - Optimal hatch occurs at 17 C and 7 $^{o}/oo$ in darkness (Leim 1924).

ACCLIMATION - No information available.

OXYGEN - Shad eggs were collected in the Neuse River within a range of 6 to 10 ppm dissolved oxygen (Hawkins 1979).

SUSPENDED SEDIMENTS - Shad egg hatching success was not affected by suspended sediment concentrations of less than 100 mg l^{-1}. Larvae were less tolerant, however; those exposed to 0.1 mg l^{-1} for 96 hours had significantly reduced survival. These values are similar to natural and man-induced changes in estuarine sediment loading (Auld and Schubel 1978).

pH - Shad eggs in the Neuse River were collected within a range of 6.4 to 6.9 (Hawkins 1979).

CURRENT - Shad eggs need sufficient water current to keep them suspended in the water column for successful development (Sholar 1977a).

3.6.5.3 Swimming Ability

No information available.

3.6.5.4 Chemical Tolerances

LEAD - Shad eggs were not significantly affected by lead levels of approximately 15 mg l^{-1} (Whitworth 1969).

3.6.5.5 Pressure

No information available.

3.6.6 Life History - Juveniles

3.6.6.1 Nutrition and Growth

FEEDING - Juvenile shad begin feeding in late afternoon, are most active at dusk, continue to a lesser extent during night, and almost cease feeding by mid-day (Massmann 1963).

Feeding ceases below 4.4 C (Chittenden 1972b). Primary food items are aquatic and terrestrial insects and crustaceans (Davis and Cheek 1966, Massmann 1963, Levesque and Reed 1972, Williams and Bruger 1972). Young shad are apparently selective feeders. Connecticut River shad exhibited a positive selection for tendipedid (chironomid) pupae and crustaceans and a negative selection for tendipedid (chironomid) larvae and hydropsychid larvae (Levesque and Reed 1972). Stomachs of juvenile shad in offshore North Carolina waters all contained one to five anchovies, Anchoa hepsetus (Holland and Yelverton 1973). Anchoa mitchelli diaphana and Gambusia affinis holbrooki were found in juvenile St. Johns River shad 73 to 88 mm fork length (FL) (Williams and Bruger 1972).

GROWTH - Juvenile shad on spawning grounds are usually smaller than those below tidal stretches of the river (Walburg and Nichols 1967). Hudson River shad grew from 15 mm in June to 89 mm in October (Walburg and Nichols 1967). Shad collected in the Neuse and Trent Rivers ranged from 31 mm in May to 95 mm in November with an average of 50 mm FL in August (Hawkins 1979);

greatest abundance occurred in July and August at 45 to 82 mm FL (Marshall 1977). Growth rates of young shad in the Cape Fear, Northeast Cape Fear, and Black Rivers were similar (Davis and Cheek 1966). From June through November (19 weeks), Altamaha River shad grew from an average fork length of 48.0 to 84.7 mm and weight increased from 1.25 to 8.67 g (Smith 1968). Rapid growth of shad (51.0 to 87 mm in five months) was observed by Godwin and Adams (1969) until October when they left the Altamaha River system at 90 to 100 mm. St. Johns River shad grew an average of 59.8 mm from May through December 1969 and 73.9 mm average during the same period in 1970 (Williams and Bruger 1972).

METABOLISM - No information available.

3.6.6.2 Hardiness

The effects of handling young American shad vary, with the intensity of excitement generated by handling seeming to determine whether the fish lives, dies immediately, or dies later. This phenomenon is probably the cause of conflicting reports on oxygen requirement and salinity and temperature tolerances (Chittenden 1973).

SALINITY - Young shad can tolerate salinity changes, especially salinity increases. Shad survived abrupt changes from 0-5 to 30 $^{o}/oo$; complete mortality occurred with abrupt decreases from 30 to 0 $^{o}/oo$. A gradual decrease from 5 to 0 $^{o}/oo$ did not cause mortality. Instances of apparent intolerance to salinity changes as reported in the literature may have been caused by handling stress. This euryhaline ability permits juveniles to utilize brackish and freshwater nurseries (Chittenden 1973).

TEMPERATURE - Lower thermal tolerance of juvenile shad was reported as 2.2 C (Chittenden 1972b) and 3-4 C (Blair 1977). Sublethal temperature effects are evident at temperatures below 6 C. These are: extremely sluggish movements, cessation of feeding, frequent temporary equilibrium loss, wobbly swimming, and frequent collision with objects shortly before death. Therefore, juveniles may not survive prolonged exposure to 4 to 6 C particularly during autumn and early winter when the fish may not be acclimated (Chittenden 1972b). Juvenile shad avoided rapid temperature increases of 4C above acclimation temperature in experimental tanks, while responses to rapid 1 C changes were not consistent, suggesting that young shad are capable of avoiding

potentially lethal temperature changes (Moss 1970). Young shad emigrating from the Connecticut River avoided heated effluent (above 30 C), which suggested that the upper natural temperature limit of juvenile shad may be about 30 C (Marcy et al. 1972).

SALINITY-TEMPERATURE INTERACTION - At temperatures of 7.2 to 26.7 C and salinities of 10 to 35 $^{o}/oo$, juvenile shad survived a saltwater to freshwater transfer but not a freshwater to saltwater transfer (Tagatz 1961).

ACCLIMATION - No information available.

OXYGEN - Equilibrium losses reported in the literature range from dissolved oxygen levels of 1.1 to 8.0 mg l^{-1}, and reports of death range from levels of 0.9 to 5.7 mg l^{-1}. Chittenden's (1973) study showed no young shad lost equilibrium at 0.68 and/or died at 0.64 mg l^{-1}. Minimum daily dissolved oxygen levels of 2.5 to 3.0 mg l^{-1} should permit juvenile migration through polluted areas, and levels of 4.0 mg l^{-1} are necessary for spawning areas (Chittenden 1973). Juvenile shad spent more time in high oxygen concentrations when exposed to dissolved oxygen gradients (Dorfman and Westman 1970). Apparently there was no instinctive ability to quickly recognize and avoid waters of low dissolved oxygen concentration. Shad that are engulfed by - or that swim into - waters with oxygen concentrations as low as 0.5 mg l^{-1} can probably survive for at least five minutes at that concentration if given access to an area of higher dissolved oxygen levels (above 3.0 mg l^{-1}) (Dorfman and Westman 1970).

SUSPENDED SEDIMENTS - No information available.

3.6.6.3 Swimming Ability

No information available.

3.6.6.4 Chemical Tolerances

Pollution is the biggest problem affecting the Delaware shad fishery. Survival of young is dependent on river flows sufficiently high to dilute pollution to tolerable levels. The Interstate Commission on the Delaware River Basin recommended reducing pollution to three billion gallons per day, a level probably insufficient to insure shad survival (Sykes and Lehman 1957).

KEPONE - All juvenile shad collected in the nursery zone of the James River near Hopewell, Virginia, contained concentrations of Kepone exceeding the action level (3.0 ppm). Mean concentrations were 1.38 ppm Kepone (Loesch et al. 1977). Juveniles in September 1978 contained mean concentrations of 0.80 ppm, a significantly higher value than those for alewife (0.58), blueback (0.24-0.51), or striped bass (0.57) (Johnson et al. 1978). York River juvenile shad contained mean Kepone concentrations of only 0.02 ppm (Loesch et al. 1977).

3.6.6.5 Pressure

No information available.

3.6.7 Life History - Adults

3.6.7.1 Longevity

Little information is available on the average life expectancy of adult shad. The average age of spawning fish in southern waters is four to five years with some seven-year-old females reported; most die after their first spawning. Mid-Atlantic shad are usually four to seven years old with occasional catches of 11- and 12-year-old fish (Table 3.6-5).

3.6.7.2 Nutrition and Growth

FEEDING - Adult shad consume little or no food during freshwater migration (Liem 1924, Leach 1925b, Moss 1946, Atkinson 1951). Opportunistic feeding on "planktonic" items may occur, but in quantities insufficient to maintain body weight in freshwater (Chittenden 1976b). While residing in offshore waters, adults are zooplankton feeders and consume primarily large copepods, mysids, and euphausids (Bigelow and Schoeder 1953, Hildebrand 1963, Leim and Scott 1966). Shad feed at all depths but particularly where zooplankton are concentrated (i.e., closer to the bottom during daylight hours), indicating that they are vertical migrators following the zooplankton (Neves and Depres 1979). The stomachs of the adult shad in offshore North Carolina water contained zooplankton (amphipods, copepods, isopods, cumaceans, decapod larvae, and bivalves), the majority under five mm in size. However, 95.1% of all stomachs also contained fish and 22% contained one to 12 Anchoa hepsetus 40 to 70 mm long (Holland and Yelverton 1973).

METABOLISM - Glebe (1977) determined variables that influence the rate and extent of energy utilization in migrating adult shad: distance to spawning areas, water temperature, current velocity, and extent of gonad

development in fresh water. In Florida, the long migration to the spawning grounds depleted energy resources by 70 to 80% or 4.5 kcal kg^{-1} km upriver displacement. Shorter migrations in Virginia and Connecticut depleted body resources only 30 to 60% or 4.5 kcal kg^{-1} km in Virginia and 6.8 kcal kg^{-1} km in Connecticut. Greater migration efficiency occurred in Florida and Virginia due to reduced current velocities. Higher water temperatures in Connecticut during the latter migration period reduced migration efficiency (8.8 vs 5.7 for earlier migrants). Extensive gonad development in Connecticut and Virginia shad during oceanic feeding reduced energy demands during their freshwater fast. Florida shad showed a 20 to 80% increase in gonad energy content during their freshwater stay (Glebe 1977). Adult shad in the Altamaha River exhibited fat content comprising 5.1 to 17.8% of their total body weight. Fat content did not decrease with distance upstream, probably because of the relatively short and easy passage. The expected decrease may have been due to small sample size (Perkins and Dahlberg 1971). Weight loss of migrating Delaware River shad was related to sex and increased with increased size (Chittenden 1976b). Males and females of average length lost 45 to 57% of their total body weight during migration, averaging 5.75 g for males and 12.47 g for females (Chittenden 1976b).

3.6.7.3 Hardiness

SALINITY - Shad adults were transferred from saltwater to freshwater in 2.5 hours and suffered heavy mortality beginning five hours after the initial reduction in salinity to start the transfer process. Sodium and chloride levels in the blood of the transferred group declined sharply during and after the transfer. Calcium, glucose, and lactic acid levels increased, while potassium and magnesium levels remained stable (Leggett and O'Boyle 1976).

TEMPERATURE - Water temperature, through its influence on metabolic rate, influences the rate and magnitude of energy utilization during spawning migration and as a result appears to influence survival. Late migrants to the Connecticut River experience 5 C higher temperatures than peak migrants. Further increases in average water temperatures can be expected to directly influence migration energetics in the Connecticut or other rivers (Glebe 1977).

SALINITY-TEMPERATURE INTERACTION - Adult shad are tolerant to tranfers from freshwater to saltwater at temperatures 7.2 to 26.7 C and 10 to 35 $^{o}/oo$. There is some tolerance from saltwater to freshwater at limited temperature differences (Tagatz 1961).

ACCLIMATION - No information available.

OXYGEN - Low levels of dissolved oxygen from pollution prohibit passage of adult shad to upriver spawning areas in the Delaware River (Chittenden and Westman 1967, White et al. 1969).

SUSPENDED SEDIMENTS - No information available.

pH - No information available.

TRANSPORT - Adult shad transported for transplant (in 1952) showed a decreased survival rate with increased hauling distance. Survival to the point of release was 89% and 68% survived after transplanting. Most shad that descended the dams (in Maryland) came through the floodgates (Walburg 1954).

3.6.7.4 Swimming Ability

Shad adults appear capable of swimming modest distances in relatively high water velocities, but even the lowest velocity tested might present a serious barrier for some shad if a passage of more than a few feet was required (Weaver 1965).

The migration rate of shad, near the speed of maximum metabolic efficiency (1 bodylength s^{-1}), may be an adaptation to maximize spawning success and postspawning survival by reducing the energetic cost of swimming. For Florida shad, all expendible energy is used to reach spawning grounds. Any significant reduction in swimming efficiency would result directly in reduced fitness (Glebe 1977).

3.6.7.5 Chemical Tolerances

KEPONE - Adult shad sampled from the James and York Rivers, Virginia, in March 1977 indicated little or no contamination (Loesch et al. 1977); adults collected from the York River in 1978 had mean concentrations of 0.04 ppm in body tissue and 0.14 ppm in roe (Johnson et al. 1978).

3.6.7.6 Pressure

No information available.

3.6.8 Behavior

3.6.8.1 Juvenile Migration and Local Movement

NURSERIES - The importance of brackish water nurseries probably depends on the rate of seaward dispersal of the young and the proximity of brackish water to the primary spawning grounds (Chittenden 1973). Nursery areas of specific river systems are listed in Table 3.6-4.

MIGRATION - Atlantic coast rivers contain discrete populations of juvenile American shad, based upon differences in meristic characters (Nichols 1966b). Juveniles leave their natal streams in autumn and generally remain in the ocean for three to five years before returning to their natal streams to spawn (Neves and Depres 1979). Winters are probably spent in the mid-Atlantic area; each summer juveniles migrate to the Gulf of Maine with the adults (Neves and Depres 1979).

CONNECTICUT RIVER - Juvenile emigration began at 16 C (early October) and was completed when water temperature reached 10 C (Scherer 1975).

VIRGINIA - Juvenile shad remain in freshwater until the temperature drops in October and November, though they move further downstream as fall progresses. Most leave the estuary in early fall and some overwinter in lower Chesapeake Bay (Davis 1973).

NEUSE RIVER - Young are present from June through October and are most abundant in July (Hawkins 1979). Shad disperse throughout the middle Neuse River and appear to be more abundant over sand or gravel bottom (Walburg and Nichols 1967, Hawkins 1979). They remain in fresh or brackish Neuse waters until October or November when they migrate to the ocean (Hawkins 1979).

CAPE FEAR SYSTEM - Juveniles migrate seaward in October and November from the Cape Fear and Northeast Cape Fear Rivers (Davis and Cheek 1966, Fischer 1980). Migration was associated with increased water levels and decreased water temperature (Davis and Cheek 1966).

Table 3.6-4. Nursery areas of juvenile American shad.

RIVER SYSTEM	NURSERY AREAS	SOURCE(S)
Tar-Pamlico system	91% of juveniles were caught from Hardee Creek to the Cannon Swamp area in July	Hawkins (1979)
Neuse-Trent system	Neuse - General area: S.R. 1224 bridge upstream from Goldsboro (RM 145) to Duck Creek downstream from New Bern (RM 35). Highest concentrations near the S.R. 1224 bridge above Quaker Neck Dam and also around S.R. 1152 bridge upstream from Kinston near Taylor Creek	Hawkins (1979)
	Trent - Pollocksville downstream to the mouth of Island Creek	Marshall (1977)
Cape Fear system	Cape Fear - 6 miles below Wilmington to Gray's Creek (RM 99) near Lock and Dam No. 3	Fischer (1980)
	Northeast Cape Fear - mouth to N.C. Hwy 24 bridge (107.8 km)	Davis and Cheek (1966)
	Black - mouth to N.C. Hwy 411 bridge (56.3 km)	Davis and Cheek (1966)
Waccamaw-Pee Dee system	Summer: RM 15 to RM 40 Fall: Winyah Bay	Crochet et al. (1977)
Altamaha River	All river zones utilized Primary nursery areas: RM 20 to RM 40 and RM 100 to RM 130 Secondary nursery areas: RM 50 to RM 60 and RM 80 to RM 90 Concentrations highest in upper river and lowest in estuary	Smith (1968) Godwin and Adams (1969)

Table 3.6-4. Nursery areas (cont'd.).

RIVER SYSTEM	NURSERY AREAS	SOURCE(S)
St. Johns River	Primary: the tidal fresh-water area north of Lake George (RM 50) during summer. General: approximately RM 195 to RM 125 near Deland	Williams and Bruger (1972) Cheek (1966) Williams et al. (1975)

OFFSHORE NORTH CAROLINA - Juveniles were emigrating from nursery areas as late as February 1970 (Holland and Yelverton 1973).

WINYAH BAY SYSTEM - Young shad spend the summer in the lower river (RM 15 to RM 40) and migrate to Winyah Bay by December and into the ocean by February (Crochet et al. 1977).

ALTAMAHA RIVER - Downstream movement begins in early July with complete emigration by December and dispersal into the ocean by January. Emigration was correlated with water temperature and not river level or water chemistry (Godwin and Adams 1969).

ST. JOHNS RIVER - Juvenile movement patterns are related to current and water temperature. Downstream movement from spawning grounds to nursery areas is correlated with increased water temperature in the spring. Emigration from the river is correlated with decreased water temperatures in the fall. Shad leave the river at 69 to 110 FL (Williams and Bruger 1972). Low-flow conditions in February and March 1971 prolonged the presence of juveniles within the river due to lack of current, resulting in an inability to find their way downstream (Williams and Bruger 1972).

3.6.8.2 Adult Migration and Local Movement

Based upon extensive review of the literature, Neves and Depres (1979) hypothesized the offshore migration pattern of American shad: "Offshore movements are limited to areas and depths with near bottom temperatures between 3 and 15 C and occur most frequently in offshore areas of intermediate depths (50 to 100 m). The adults which survive spawning, together with subadults, migrate to the Gulf of Maine or to an area south of Nantucket Shoals and remain there through summer and early autumn. During this period, shad feed actively and appear to migrate vertically following the diel movements of zooplankton in the water column. Most shad move out of the Gulf of Maine in autumn with declining water temperature and congregate offshore between Long Island and Nantucket Shoals (Latitude 39 to 41^{o} N) during the winter. Adults enter coastal waters in a broad front toward the middle Atlantic coast as far south as North Carolina during the winter and spring.

Adult shad populations returning to South Atlantic States migrate south adjacent to the coast and within the 15 C isotherm to reach home rivers by winter and early spring. North Atlantic populations proceed up the coast in spring with warming waters above 3 C. Seasonal shifts in isotherms, as influenced by circulation patterns, are of greatest importance in defining the migratory route of shad" (Neves and Depres 1979).

American shad may home not only to their natal river but also to their natal tributary (Carscadden and Leggett 1975a). Canadian and U.S. shad populations begin moving inshore to spawn in January and February after spending the summer and fall on the summer feeding grounds in the Gulf of Maine. Catches in Chesapeake Bay and the sounds of North Carolina from late November to early December are believed to be adults returning to natal rivers farther south (Neves and Depres 1979). In general, most shad populations north of Cape Hatteras begin entering rivers at 4 C and the peak upstream migration occurs at temperatures of 10 to 15 C (Leggett and Whitney 1972). Most shad begin to return seaward by late June after a maximum of about two months in freshwater. Many remain near the spawning grounds, probably from starvation (Chittenden 1976b).

Tagging studies by M.J. Dadswell in the Bay of Fundy indicate that shad from most U.S. rivers congregate in the upper Bay of Fundy to feed during summer. The population migrates counterclockwise and enters all bays and basins in sequence - starting with the Annapolis River, Nova Scotia, and ending with the Saint John River, New Brunswick (M.J. Dadswell, unpublished data).

Tagging studies by Dodson et al. (1972) and Leggett and O'Boyle (1976) showed that adult shad exhibit extensive meandering at the upper limit of the saltwater-freshwater interface during spawning migration. This may be a behavioral response designed to slow the transition from a saltwater to freshwater environment, thereby minimizing the physiological stress and allowing full recovery from stress before proceeding upstream (Leggett and O'Boyle 1976).

SAINT JOHN RIVER - Movement of American shad into the Saint John River estuary, New Brunswick during fall 1973 was thought not to be a spawning migration but rather part of the Saint John River population (Gabriel et al. 1976).

CONNECTICUT RIVER - Upstream movement begins in late March to early April with peak abundance at 13 C (Leggett and Whitney 1972).

NEW RIVER - Anadromous resources are limited, and a relocation of the fish distribution appears to be occurring. Upstream utilization in 1974 switched to downstream tributaries in 1975 possibly due to upstream channelization (Sholar 1975).

CAPE FEAR SYSTEM - Adult shad first appear in February in the lower Cape Fear River and remain until May. Peak run in the Cape Fear and Northeast Cape Fear Rivers occurs in April (Fischer 1980).

OFFSHORE NORTH CAROLINA - Shad occur from January through April at bottom temperatures of 6 to 12 C and depths less than 26 m (Johnson et al. 1978). Adults were migrating to freshwater spawning areas, not necessarily in North Carolina, as late as March 1971 (Holland and Yelverton 1973). During 1978, 71.8% of all shad were collected from 18.4 km NNE of the Cape Hatteras Lighthouse to the Chesapeake Bay entrance (Johnson et al. 1978). Catches declined at temperatures above 12 C, suggesting movement into estuaries or northward (Johnson et al. 1978).

WINYAH BAY SYSTEM - Adult shad were collected from January through April in the Waccamaw and Pee Dee Rivers. Greatest abundance occurred during March 1975 and 1976 (Crochet et al. 1977).

ST. JOHNS RIVER - The upstream limit for adult shad is the Salt-Loughnam-Ruth Lake region. Oklawaha River is the largest tributary, and adults are found from the river mouth to the Moss Bluff Dam but not above the dam (McLane 1955). Migration begins in December and continues into late March or early April. Shad have a slightly longer migration period than blueback herring and do not show such a pronounced increase and decrease in abundance at the beginning and end of the spawning run as do herring (Williams et al. 1975). During the 1969-70 season, spawning began in December and continued through May, reaching a peak in February and March (Williams and Bruger 1972). McLane (1955) suggested that adults returned to sea after spawning, as there were no reports of dead adults.

3.6.8.3 Responses to Stimuli

LIGHT - Light intensity seemed to regulate when spawning in Delaware tributaries began each day (Chittenden 1976a). Adult shad entered the Holyoke Dam fishlift only in daylight hours with the peak occurring shortly after noon (Scherer 1975). A study by Katz (1978) revealed that, under laboratory conditions, shad exhibit a diurnal exogenous rhythmicity in swimming rate and number of individuals within a school. Fast swimming speeds - up to 45 cm s^{-1} - and schooling occurred during "daylight," and under dark conditions speeds were slower (8 cm s^{-1}) with most fish swimming individually. Under constant light, equivalent to bright moonlight, no schooling was evident and swimming rates were constant and slow. The results suggested a lack of endogenous activity rhythm, which suggests that light cueing mechanisms for swimming activity may not be for navigation during migration but perhaps relate to other activities such as feeding (Katz 1978).

TEMPERATURE - Laboratory experiments and temperature monitoring of rivers with major shad runs indicate that the timing of diadromous movements corresponds with specific water temperatures (Walburg and Nichols 1967; Chittenden 1969, 1972b; Williams and Bruger 1972; Leggett and Whitney 1972; Leggett 1973). Oceanic distribution of shad was postulated to be controlled by the 13 to 18 C isotherm (Leggett and Whitney 1972). Temperature sets limits on when adults can enter and young must leave freshwater. It masks the stimulus for upstream migration associated with gonadal stimulus. Decreasing temperature in northerly rivers triggers final exodus of young from freshwater. Shad behavior in temperature avoidance and resistance lowers the probability of mortality due to catastrophic temperature decreases (Chittenden 1972b).

AVOIDANCE BEHAVIOR - American shad tagged with transmitters exhibited great ability to avoid commercial gill nets. Shad moved to within one to two m of the net before sensing its presence, then turned and swam along the net close to the mesh to the end, where they turned and continued their upriver migration. Sight appeared important in net detection but avoidance also occurred in reduced light, suggesting that other sensory mechanisms (e.g., lateral line) function in net avoidance (Leggett and Jones 1971).

3.6.9 Population

3.6.9.1 Sex Ratio

Sex ratios for American shad populations are difficult to determine due to collection techniques and commercial practices of harvesting and marketing. Gill nets are selective for female shad because of their large size compared to males and bring higher prices, especially if the females are "roe" shad.

DELAWARE RIVER - Male shad tended to precede females in spring runs. The annual sex ratio was strongly male-dominated in 1961 through 1963 and female-dominated from 1964 to 1965 (Chittenden 1975).

ALBEMARLE SOUND - Male to female ratio was 1.34:1 in 1977 (Loesch et al. 1977) and 1.4:1 in 1978 (Johnson et al. 1978).

NEUSE RIVER - Females were slightly more abundant in 1978; sex ratio was 1:1.5 (Hawkins 1979).

CAPE FEAR RIVER - Males dominated females 1.2:1 in 1978 and 2.8:1 in 1979 (Fischer 1980). Scholar (1977a) reported males outnumbered females 4.7:1, indicating a problem in overexploitation of the Cape Fear shad stock.

OFFSHORE NORTH CAROLINA - During 1970-71, females dominated the population with a sex ratio of 1:5.5 (Holland and Yelverton 1973).

ST. JOHNS RIVER - During the period 1964 through 1971, males dominated the population, ranging from 1:1 in 1966 to 2.0:1 in 1968 and averaging 1.6:1 over the nine-year period (Williams and Bruger 1972).

3.6.9.2 Age Composition

Most shad populations on the Atlantic coast are comprised primarily of age classes IV, V, VI, and VII. Age class V dominates the female population while most male spawners are ages IV and V. Few Mid-Atlantic or South Atlantic populations have repeat spawners (Table 3.6-5).

3.6.9.3 Size Composition

Male shad are usually smaller than female shad of similar age (Table 3.6-6).

Table 3.6-5. Age composition (%) of American shad populations in river systems along the Atlantic coast. M = males; F = females; C = sexes combined.

RIVER SYSTEM AND YEAR	SEX	II	III	IV	V	VI	VII	VIII	>VIII	SOURCE(S)
Delaware River										
1975	M		3.0	76.0	20.0	<0.1	-			Chittenden (1975)
	F		-	14.0	62.0	24.0	<0.1			
Albemarle Sound										
1977	M			23.0	65.2	11.7	-			Loesch et al.(1977)
	F			1.2	55.0	41.5	2.3			
1978	M		1.0	18.5	64.4	13.4	2.7			Johnson et al.(1978)
	F		-	4.5	55.6	39.4	0.6			
Chowan River										
1971	C				32.4	38.2	29.4			Holland and Yelverton (1973)
Offshore NC										
1971	C	1.5	-	3.0	10.4	39.6	30.6	11.2	3.7	Holland and Yelverton (1973)
Northeast Cape Fear River										
1976	M			85.0	13.0	2.0	-			Sholar(1977a)
	F			18.0	64.0	9.0	9.0			
1978-79	M			51.0	42.0	5.0	2.0			Fischer(1980)
	F			5.0	70.0	25.0	-			
Cape Fear River 1978-79	M		1.0	59.0	39.0	1.0	-			Fischer(1980)
	F		-	18.0	43.0	36.0	3.0			

Table 3.6-5. Age composition (cont'd.).

RIVER SYSTEM AND YEAR	SEX	AGE CLASS II	III	IV	V	VI	VII	VIII	> VIII	SOURCE(S)
New River										
1974-75	M			50	50					Sholar(1975)
	F			-	100					
White Oak River										
1974-75	M			53	47	-	-			Sholar(1975)
	F			13	56	25	6			
Neuse River										
1977	M		14	48	25	10	3			Marshall(1977)
	F		-	6	52	40	2			
1978	M		2	34	58	6	-			Hawkins(1979)
	F		-	2	67	30	1			
Waccamaw & Pee Dee Rivers										
1974	M	2	20	63	16	-				Crochet et al.(1974)
	F	-	8	43	35	14				
1975	M		14	76	10	-	-			Crochet et al.(1975)
	F		3	52	41	3	1			
1976	M		4	74	22	-				Crochet et al.(1976)
	F		-	35	62	3				
Santee River										
1974	M		38.6	49.5	9.9	2.0	-			Curtis(1974)
	F		-	7.6	64.9	22.9	4.6			
Edisto River										
1971	M		34	55	11	-				Wade(1971)
	F		-	9	80	11				

Table 3.6-5. Age composition (cont'd.).

RIVER SYSTEM AND YEAR	SEX	AGE CLASS II	III	IV	V	VI	VII	VIII	> VIII	SOURCE(S)
Ogeechee River 1956	C		1.3	41.4	48.0	9.3				Sykes (1956)
Altamaha River 1967-68	M		12.8	49.0	36.1	1.9	0.2	-	-	Godwin (1968)
	F		0.5	25.6	62.2	10.8	0.6	0.3	-	
St. Johns River 1972	M		44.8	26.0	27.3	1.9				Williams et al. (1975)
	F		1.9	11.8	73.3	13.0				
1973	M	-	22.9	72.3	2.8	2.0	-			Williams et al. (1975)
	F	0.5	2.3	66.5	16.1	14.2	0.5			

Table 3.6-6. Size composition (mean fork length in mm) of American shad in river systems along the Atlantic coast. M = males; F = females; C = sexes combined.

RIVER SYSTEM	SEX	AGE CLASS I	II	III	IV	V	VI	VII	VIII	IX	X	XI	SOURCE(S)
Delaware River													
	M			374	426	458	478						Chittenden (1969)
	F			-	451	476	526						
Susquehanna River	M	165	267	330	376	404							LaPointe (1958)
	F	175	284	361	404	444							
Albemarle Sound													
	M			359	400	432	450	461	476				Street et al. (1975)
	F			-	437	473	498	540	509				
Neuse River													
	M	178	287	368	422	-	-						LaPoint (1958)
	F	183	295	376	429	472	513						
	M			375	400	426	441	455					Marshall (1977)
	F			-	428	459	483	494					
	M			352	397	414	423	-					Hawkins (1979)
	F			-	444	463	481	521					
Pamlico Sound and River	M			334	415	437	456	470	485				Marshall (1976)
	F			-	445	481	494	489	532				
Offshore North Carolina	C				429	451	458	467	486	488	464	547	Holland and Yelverton (1973)

Table 3.6-6. Size composition (cont'd.).

RIVER SYSTEM	SEX	AGE CLASS I	II	III	I.	V	VI	VII	VIII	IX	X	XI	SOURCE(S)
Cape Fear River	M			380	403	430	440	-					Fischer (1980)
	F			-	424	461	490	525					
Northeast Cape Fear River	M				404	433	487	513					Fischer (1980)
	F				390	462	496	-					

3.6.9.4 Abundance and Population Status

Commercial landings of American shad have been in decline since the turn of the century throughout river systems of the eastern seaboard. Mark-recapture programs have aided in determining the approximate population sizes of various stocks returning to natal rivers during spring (Table 3.6-7). Detailed information is lacking for many river systems throughout Region 4.

The status of American shad populations in river systems throughout Region 4 was estimated from responses to a questionaire submitted to various State, Federal and other agencies. From these responses, it appears that the majority of American shad stocks within Region 4 are in various states of decline (Table 3.6-8). Several spawning runs appear threatened. Factors possibly important in contributing to declining stocks are listed in Table 3.6-9.

Shad runs estimated from 1935 to 1951 indicated that 80% of the fluctuation in population size was explained by the size of escapement from the fishery (Fredin 1954). Escapement rate for the Edisto River was 80% in 1955 (Walburg 1956). During 1974 through 1976, the shad escapement rate in the Waccamaw-Pee Dee system was 80% for males and 68% for females (Crochet et al. 1977).

3.6.9.5 Factors Affecting Reproduction and Recruitment

Glebe (1977) suggested that shad appear to be highly adapted both energetically and reproductively to their home rivers. Large body size and later mean age at maturity of Connecticut River shad may be an adaptation to increasing energy resources and thereby enhance postspawning survival necessary for population stability in a fluctuating environment. Florida shad maintain a high reproductive potential, despite small body size and complete postspawning mortality, by greatly increasing their relative fecundity. Higher fecundity is possible by a reduced allocation of energy per ovum (0.4 cal vs. 1.3 cal for Virginia and Connecticut populations)(Glebe 1977).

A pollution block in the lower Delaware River has resulted in low levels of dissolved oxygen and is thought to prohibit passage of adult shad to upstream spawning areas (Chittenden and Westman 1967; White et al. 1969). Few year classes are successful, few age

Table 3.6-7. Population estimates of American shad stocks ascending various river systems along the Atlantic coast.

RIVER SYSTEM	YEAR	POPULATION ESTIMATE	SOURCE(S)
Connecticut River	1975	598,000	Jones et al. (1977)
	1976	740,000	Jones et al. (1977)
Delaware River (passing Lambertville New Jersey)	1976	178,760	Friedersdorff (1977)
Waccamaw-Pee Dee system	1974	73,000	Crochet et al. (1977)
	1975	76,000	Crochet et al. (1977)
	1976	89,000	Crochet et al. (1977)
Altamaha River	1967	471,345	Godwin (1968)
	1968	989,213	Godwin (1968)
Edisto River	1955	56,000 (28,000-100,000)	Walburg (1956)
St. Johns River	1965	3,695,000 pounds entered river to spawn	Cheek (1966)

Table 3.6-8. Status of American shad, *Alosa sapidissima*, in river systems within Region 4 based on questionnaire responses to question VI-2. S = response from marine representative; F = response from freshwater representative.

RIVER SYSTEM	STATUS
NORTH CAROLINA	
Currituck Sound	
Albemarle Sound	Declining (SF)
North R.	
Pasquotank R.	
Little R.	
Perquimans R.	
Yeopim R.	
Chowan R.	Declining (SF)
Meherrin R.	Declining (S)
Roanoke R.	Declining (SF)
Cashie R.	Declining (S)
Scuppernong R.	
Alligator R.	
Pungo R.	
Pamlico R.	
Tar R.	Declining (SF)
Neuse R.	Declining (SF)
Trent R.	Declining (S)
Newport R.	
White Oak R.	Not known (S)
New R.	Threatened (S)
Cape Fear R.	Declining (SF)
Northeast Cape Fear R.	Declining (SF)
Black R.	Not known (S)
Pee Dee R.	Declining (F)
SOUTH CAROLINA	
Waccamaw R.	Stable (SF)
Little Pee Dee R.	Stable (F)
Great Pee Dee R.	Stable (SF)
Black R.	Stable SF)
Santee R.	Declining (S), Stable (F)
Cooper R.	Stable (SF)
Ashley R.	Stable (SF)
Edisto R.	Declining (S), Stable (F)
Ashepoo R.	Stable (SF)
Combahee R.	Stable (SF)
Sampit R.	Increasing (S), Stable (F)
Salkehatchie R.	Stable (F)
Lynches R.	Stable (S)
Savannah R.	Stable (SF)

Table 3.6-8. American shad (cont'd.).

RIVER SYSTEM	STATUS
GEORGIA	
Savannah R.	Not known (SF)
Ogeechee R.	Declining (S), Not known (F)
Altamaha R.	Not known (SF)
Oconee R.	Not known (F)
Satilla R.	Declining (S), Not known (F)
Ocmulgee R.	Not known (F)
St. Marys R.	Declining (S), Not known (F)
FLORIDA (Atlantic Coast)	
St. Marys R.	Declining (S), Stable (F)
Nassau R.	Not known (S), Stable (F)
St. Johns R.	Declining (S), Stable (F)
Pellicer Cr.	Declining (S)
Moultrie Cr.	Probably never present (S)
Tomoka R.	Declining (S)

Table 3.6-9. Factors possibly important or very important in contributing to the decline of certain populations of American shad, *Alosa sapidissima*, within Region 4 based on questionnaire responses to question I. S = response from marine representative; F = response from freshwater representative; C = response from other agencies.

NORTH CAROLINA

- Channelization (FC)
- Dredge and fill projects (F)
- Dams and impoundments (FC)
- Industrial water intakes (FC)
- Location of industrial discharges (FC)
- Chemical pollution (F)
- Turbidity (F)
- Low oxygen levels (F)
- Sewerage outfalls (C)
- Inadequate fishway facilities (F)
- Inadequate control of water release from dams (C)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)
- Poor food availability (F)
- Spawning areas too accessible to fishermen (C)
- Poor water quality (FC)

SOUTH CAROLINA

- Dams and impoundments (S)
- Inadequate fishway facilities (S)
- Reduction in spawning habitats (S)
- Poor water quality (S)

GEORGIA

- Channelization (S)
- Dredge and fill projects (S)
- Dams and impoundments (S)
- Location of industrial discharges (S)
- Chemical pollution (S)
- Thermal effluents (S)
- Reduction in spawning habitats (S)
- Reduction in nursery areas (S)
- Poor food availability (S)
- Spawning areas too accessible to fishermen (S)
- Poor water quality (S)

FLORIDA

- Channelization (FS)
- Dredge and fill projects (F)
- Bulkheading (F)
- Dams and impoundments (F)
- Industrial water intakes (S)
- Location of industrial discharges (F)
- Chemical pollution (F)
- Low oxygen levels (FS)
- Sewerage outfalls (FS)
- Reduced freshwater input to estuaries (S)
- Reduction in spawning habitats (FS)
- Reduction in nursery areas (FS)
- Poor food availability (S)
- Spawning areas too accessible to fishermen (S)
- Poor water quality (FS)
- Agricultural drainage (F)
- Non-point source pollutants (S)
- Overfishing (S)

groups support the run, and there are essentially no repeat spawners; only 2.6% of the shad examined from 1963 to 1965 were repeat spawners (Chittenden 1975).

The proportion of repeat spawners within a population is important in predicting the degree of successful spawning and survival necessary to estimate the stability of a spawning stock. The proportion of repeat spawners in a population increases with increased latitude; virtually all shad south of Cape Hatteras die after spawning, while the percentage of repeat spawners in rivers north of North Carolina increases with latitude (Leggett 1969; Chittenden 1975). The York River shad (Virginia) population contained an estimated 23% repeat spawners during the period 1953 through 1959 (Nichols and Massmann 1962). Shad populations in the Albemarle Sound and Pamlico River were comprised of only 19% repeat spawners (Street et al. 1975; Marshall 1976). By 1977, 92% of Albemarle Sound shad were virgin and only one percent had spawned more than once (Loesch et al. 1977). In 1978, 2.8% were repeat spawners with 95% of the males and 98% of the females being virgin (Hawkins 1979). In 1973, the Chowan River spawning population was comprised of 14.7% repeat spawners, with 74.5% having spawned for the first time at ages IV through VI and 26.5% at age VII (Holland and Yelverton 1973). The Neuse River appears to be the southern limit of repeat spawning activity, and south of the Neuse there are essentially no repeat spawners. In 1977, repeat spawning in the Neuse River was near 14%, with 77% of the males and 88% of the females being virgin (Marshall 1977). Less than one percent of the shad from the Northeast Cape Fear River spawned more than once, and there were no repeat spawners from the Cape Fear River (Sholar 1977a; Fischer 1980). American shad captured in offshore North Carolina waters in 1972-73 were comprised of 71.7% repeat spawners; three percent had spawned as many as four times. These shad may have been from northern stocks and not North Carolina stock (Holland and Yelverton 1973).

3.6.9.6 Mortality

FISHING MORTALITY - The annual fishing mortality for American shad populations varies from river to river. Fishing mortality within Region 4 ranges from 15% in St. Johns River, Florida, to 65% in the Neuse River, North Carolina (Walburg 1957, 1960b). Fishing mortality rates for specific populations are presented in Table 3.6-10.

Table 3.6-10. Fishing mortality rates of American shad populations in river systems along the Atlantic coast.

RIVER SYSTEM	YEAR	MORTALITY(%)	SOURCE(S)
Connecticut River	1941	32.8	Fredin (1954)
	1946	81.9	Fredin (1954)
Hudson River	1916	19.8	G.E. Talbot (1954)
	1947	79.0	G.E. Talbot (1954)
Potomac River	1944	41.9	Walburg and Sykes (1957)
	1949	76.0	Walburg and Sykes (1957)
James River	1957	73.0	Walburg and Sykes (1957)
York River	1953	58.3	Nichols and Massmann (1962)
	1958	44.4	Nichols and Massmann (1962)
	1959	55.2	Nichols and Massmann (1962)
Neuse River	1957	65.0	Walburg (1957)
Waccamaw-Pee Dee System	1974	33.9	Crochet et al. (1976)
	1975	29.0	Crochet et al. (1976)
	1976	18.5	Crochet et al. (1976)
Edisto River	1955	20.0	Walburg (1956)
Ogeechee River	1954	66.0	Sykes (1956)
Altamaha River	1967	48.6	Godwin (1968)
	1968	43.3	Godwin (1968)
St. Johns River	1960	15.0	Walburg (1960b)

NATURAL MORTALITY - Density-independent adult mortality during the spawning migration appears to be a major factor determining the life history strategy of American shad (Carscadden 1975). The long migration to the spawning grounds in Florida results in extensive utilization of energy reserves (70 to 80%) and complete postspawning mortality (Glebe 1977). Shorter migrations in Virginia and Connecticut result in reduced depletion of energy reserves (30 to 60%) and postspawning survival (Glebe 1977). Seasonal mortalities of adult shad passing through Holyoke Dam fishway ranged from 2.77 to 3.28% over a four-year period (Scherer 1975). Total mortality rates for Albemarle Shad were estimated as 82% in 1977 and 36% in 1978 (Loesch et al. 1977; Johnson et al. 1978).

3.6.10 Predator-Prey Relationships

Adult shad appear to be comparatively free of predators other than man. Porpoise may feed on adults in coastal waters (Walburg and Nichols 1967). Eels prey upon eggs and juveniles in freshwater (Mansueti and Kolb 1953, cited in Jones et al. 1978). Striped bass also prey on juvenile shad (Walburg and Nichols 1967). An adult male shad in the Russian River, California, had inflammation around an external swelling which may have originated from a lamprey bite (Warner and Karkansky 1970).

3.6.11 Diseases

A summary of studies on parasites was presented by Walburg and Nichols (1967). Shad remain relatively free of severe infestations. Parasites found to infest shad are: nematodes; roundworms *Ascaris adunca* and *Agamonema capsularia*; sea lice; acanthocephalans *Echinorhynchus acus* and Acanthocephali; *Clinostronum marginatum* (trematode); sea lamprey; and freshwater lamprey.

Aeromonas liquefaciens was established as the lethal agent in a coliform kill of American shad in California, although stress brought on by very low dissolved oxygen levels (1.2 to 2.6 ppm) was the probable cause of the epidemic (Haley et al. 1967).

Adult American shad exhibit high incidence of gas bubble disease from the air-supersaturated Columbia River (Bouck et al. 1976).

3.6.12 Exploitation

3.6.12.1 Gear

NORTH CAROLINA - Drift nets, anchored gill nets, pound nets, haul seines, and hook-and-line are the principal gear utilized to land American shad in North Carolina. During the period 1960 to 1970, gill nets comprised 56% of all landings, pound nets contributed 41%, and haul seines contributed three percent (Sholar 1977a).

SOUTH CAROLINA - Currently, only drift and set nets comprise the gear fished except for a few weirs utilized in the upper Lynches River fishery and an undetermined number of bow nets utilized for recreational purposes (Table 3.6-11)(Ulrich et al. 1979).

GEORGIA - From the 1960s until the present, drift nets and set gill nets have been utilized almost exclusively in the Georgia shad fishery, with drift nets used to a greater extent. A few otter trawls and handlines are also used, and bow nets are utilized for recreational purposes (Table 3.6-12). The Georgia sport fishery is similar to that of South Carolina, with rod and reel used to troll or cast with small darts or spoons as bait (Ulrich et al. 1979).

FLORIDA - In 1969-70, the St. Johns River shad fishery was comprised of 8800 years of gill net (Mayport) and two haul seines in a fishery between Palatka and Welaka. Three drift gill nets (100 yards long) were fished in Jacksonville Harbor and 580 yards of set gill net were used in the vicinity of Palatka (Williams and Bruger 1972).

3.6.12.2 Fishing Areas

NEUSE RIVER - Drift netting occurs near SR 1421 and SR 1449. The commercial fishery occurs from the Neuse River mouth to the mouth of Pitchkettle Creek at SR 1449 (Marshall 1977). Staked gill nets are used primarily between New Bern and the river mouth. Drift nets are used from the Flower Gap area to Pitchkettle Creek (Hawkins 1979). The inland recreational fishery for anadromous fish officially extends from the mouth of Pitchkettle Creek to Raleigh. Pitchkettle Creek is the dividing line between jurisdictional areas of the NC Division of Marine Fisheries and Wildlife Resources Commission (Hawkins 1979).

Table 3.6-11. Summary of South Carolina anadromous fishing laws and regulations (from Ulrich et al. 1979).

YEAR	SEASON	CLOSED DAYS AND AREAS	NET REGULATIONS	RECREATIONAL
1932	January 16 to March 25 below 40-mile limit January 16 to April 20 above 40-mile limit	SHAD: Sunset Friday to sunset Monday	Minimum mesh size 6 inches One half of stream must remain open Minimum of 200 yds. between nets	Minimum size hickory shad; 12 inches measured from tip of tail to tip of nose
1941	February 1 to March 25 below 40-mile limit February 1 to April 20 above 40-mile limit	SHAD: Noon Friday to Noon Tuesday	Same as 1932	Same as 1932
1952	Same as 1941	SHAD: Days- Same as 1941 Areas- area within the 3 mile limit seaward of Win-yah Bay closed to stake and an-chor nets	Savannah River: minimum mesh 4 inch stretched mesh All other areas: same as 1932 Unlawful to leave nets in water after close of season	No weekly closed period on skimbows in some areas Creel limit on striped bass 10/person/day
1959	Horry County: February 1 to May 4 above 60-mile limit All other streams same as 1941	SHAD: Days - Edisto River- Saturday noon - Wednesday noon All other streams Saturday noon - Tuesday noon Areas - same as 1952	Game Zone 7 - minimum mesh size 5¼ inches stretched All other streams same as 1952	Local provisions for skim-bow, pump, dip, and bow nets Other same as 1952

Table 3.6-11. South Carolina regulations (cont'd.).

YEAR	SEASON	CLOSED DAYS AND AREAS	NET REGULATIONS	RECREATIONAL
1962	SHAD: Same as 1959 HERRING: February 1 to April 15 on Great Pee Dee River	SHAD: Days - Berkeley and Williamsburg counties: Saturday noon to Monday noon All other areas same as 1959 Areas - same as 1952 HERRING: Saturday noon to Thursday noon	SHAD: All streams minimum mesh 5½ inches stretched Upper Edisto: 4½ inches stretched mesh All other: same as 1952 HERRING: 3 inch stretched mesh	Hook and line season for shad February 1 to May 1 with creel limit of 8 shad per day Other: same as 1959
196[illegible]	SHAD: Below 40-mile limit: February 1 - March 25 Horry County, above 40-mile limit: February 1 - May 4 Edisto River, above 40-mile limit: February 1 - April 20 All other areas, above 40-mile limit: February 1 - April 30 HERRING: March 1 - May 1 in Tail Race Canal of Cooper River Same as 1962 in Great Pee Dee River	SHAD: Days - Game Zone 5: Saturday sunset - Tuesday noon Savannah River in Game Zone 6: Saturday midnight-Tuesday sunrise Game Zone 7, Berkeley, and Williamsburg counties: Saturday noon - Monday noon All other areas: Saturday noon-Tuesday noon Areas - Savannah River: in Game Zone 3 from New Savannah Bluff Lock and Dam to point where Spirit Creek empties into river closed to fishing Combahee River: closed from US Hwy. 17 seaward All other areas: same as 1952 HERRING: Same as 1962	SHAD: Savannah River: minimum mesh of 4½ inches; in Game Zone 6, no net to exceed 200 lineal ft. in length; registered sets issued to licensed fishermen on non-renewable basis Unlawful for net to remain on bank of stream for more than 3 days after close of season All other: same as 1962 HERRING: On Cooper River in Tail Race canal, only dip or drop nets not exceeding 6 ft. in diameter lawful; catch limit of 25 dozen or 100 lbs. per trip per day	Skimbow season: February 1-May 1 Other: same as 1962

Table 3.6-11. South Carolina regulations (cont'd.).

YEAR	SEASON	CLOSED DAYS AND AREAS	NET REGULATIONS	RECREATIONAL
1971	SHAD: Same as 1969 HERRING: Same as 1969	SHAD: Days - same as 1969 Areas - Cooper River: gill net fishing prohibited in either branch of river or its tributaries from upper "T's" inland Other areas: same as 1969 HERRING: Same as 1969	SHAD: Georgetown County: no drift net to exceed ½ width of stream between mouth of Waccamaw River and Butler Island Black and Waccamaw Rivers: net length limited to 200 yds. from mouth of either river to 40-mile limit Edisto River: registered sets issued to licensed fishermen with option to renew each licensing year (15 day grace period); no more than two sets per household All other areas: same as 1969 HERRING: Same as 1969	SHAD: Same as 1969 HERRING: Same as 1969
1974	SHAD: Same as 1969 HERRING: Same as 1969	SHAD: Days - Black, Pee Dee, and Santee Rivers: Saturday noon-Monday noon Other: same as 1971 Areas - same as 1971 HERRING: same as 1969	SHAD: Same as 1971 HERRING: Same as 1969	SHAD: Same as 1969 HERRING: Same as 1969

Table 3.6-11. South Carolina regulations (cont'd.).

YEAR	SEASON	CLOSED DAYS AND AREAS	NET REGULATIONS	RECREATIONAL
1978	SHAD: Savannah River: January 15 - April 15 All other areas same as 1969 HERRING: Same as 1969	SHAD: Days - Savannah River: upstream of Interstate 95, Sunday, Monday, and Tuesday closed; downstream of Interstate 95, closed Saturday, Sunday, and Monday Game Zone 5 and 8: 1 hour after official sunset Sunday to Wednesday noon Other: Same as 1971 Areas - Savannah River: fishing prohibited in North Channel of Savannah River downstream from New Savannah Cut and in Back River Other: Same as 1974 HERRING: Same as 1969	SHAD: Savannah River: set issuing procedure changed to allow renewal of previously held sets the first 15 days of new licensing year; only 2 sets per household Savannah River: minimum mesh size increased to 4½ inches; maximum mesh size set at 5½ inches stretched mesh All other areas: Same as 1971 HERRING: limit increased to 50 dozen or 200 lbs. herring per boat per day in Tail Race canal of Cooper River; 50 doz. per boat trip in Lakes Marion, Moultrie, and the Diversion Canal	SHAD: Creel limit of 8 shad per day dropped to unlimited catch Other: same as 1969 HERRING: Same as 1969

LICENSES:	Net license	\$5.00 / 100 yds. or fraction there of
	Swim fish license (for selling fish)	\$2.50
	Boat license (up to and including 18 ft.)	\$2.50
	Boat license (over 18 ft.)	\$10.00
	Non-resident license for Savannah River	\$100.00
	Bait selling license	\$5.00

Table 3.6-12. Summary of Georgia shad laws and regulations (from Ulrich et al. 1979).

YEAR	SEASON	CLOSED DAYS & AREAS	NETS: MESH SIZE & OTHER REGULATIONS	COMMERCIAL (NET) LICENSE	RECREATIONAL OR NON-RECREATIONAL
Circa 1930's	Spawning season closed April 15 to June 1 (all fish) Set year to year by Commissioner of Game & Fish	Sunrise Saturdays to sunrise Sundays	Minimum mesh 5 inches; Maintain 10 ft. main channel of rivers and 1/3 channel of creeks open for free passage of fish. Possession or having in boat in or upon waters a net for taking shad during closed times prima facie evidence of violation.	Resident Indiv. $2.00 Non-resident 5.25 Boat 5.00	Spawning season closed April 15 to June 1 (all fish)
1952	St. Mary's River 12/15 - 4/15 All Other Streams 1/1 - 4/1	Sundown Saturday to Sunrise Tuesday	Minimum mesh 3 1/2 stretched set to allow 1/3 of stream width free for passage of fish. Nets not be set within 150' of net previously set. Possession or having in boat in or upon waters a net for taking of shad during closed times prima facie evidence of violation.	Fisherman Resident $ 1.00 Non-resident 10.00 Boat Resident--16' length + 4' beam $1.05 Over 16' L + 4'B, $1.05 plus $2.04 each additional ft. length and beam. Non-resident--resident fee + $25.00	No closed season, 5 fish/person/day (Hook & line) Same as 1953
1953	St. Mary's River 12/15 - 4/15 All Other Streams 1/1 - 4/15	Sundown Friday to Sunrise Monday	Same as 1952	Same as 1952	No closed season, limit 8/day Res. fresh water-- $1.25 N/R fresh water-- season: $5.25 day: $1.00 or same as his state's fishing license for N/R. Honorary Res. Lic. age 65 or over.

Table 3.6-12. Georgia shad regulations (cont'd.).

YEAR	SEASON	CLOSED DAYS & AREAS	NETS: MESH SIZE & OTHER REGULATIONS	COMMERCIAL (NET) LICENSE	RECREATIONAL OR NON-RECREATIONAL
1954-1958	Same as 1953	Same as 1953	Same as 1952	Same as 1952	Same as 1953
1961	Same as 1953	Same as 1953	Same as 1952	Same as 1952	No closed season limit 8/day Res. fresh water-- $1.25 N/R fresh water-- season: $6.25 3-day: $1.25 Non. Res. License age 65 or over
1962	Same as 1953	Same as 1953	Same as 1952	Same as 1952	Same as 1961
1965	St. Mary's River 12/15 to 4/15 All Other Streams 1/15 to 4/15	6 Coastal Counties: Sundown Friday to Sunrise Monday All Others: Sundown Sunday to Sunrise Wednesday	Minimum mesh 4 3/4 in. stretched Allow 1/3 of stream clear for the passage of fish. Nets not set closer than 100 ft. of net previously set. Possession or having in boat in or on waters a net for taking shad during closed time prima facie evidence of violation.	Same as 1952	Same as 1961
1967	Same as 1965	E. Seaboard RR: Sundown Friday to sunrise Monday W. Seaboard RR: Sundown Sunday to sunrise Wednesday	5 1/4 in. stretched Other same as 1965	<u>Fisherman</u> <u>Resident</u> $ 5.00 Non-resident 100.00 <u>Boat</u> Res. 18' 5.00 Over 18' $5.00 plus $.50 each foot over 18. Non-resident-- resident fee + $25.00	No closed season 8/day--2 poles & lines. Res. season $2.25; N/R season $7.25; N/R 5-day $2.25 Bow nets allowed with sport license

Table 3.6-12. Georgia shad regulations (cont'd.).

YEAR	SEASON	CLOSED DAYS & AREAS	NETS: MESH SIZE & OTHER REGULATIONS	COMMERCIAL (NET) LICENSE	RECREATIONAL OR NON-RECREATIONAL
1968	St. Mary's River 12/15 - 4/15 All Other Streams 1/15 - 4/1	Midnight Friday - Midnight Sunday all areas	Minimum 4 1/2 in. stretched ; other same as 1965	Same as 1967	Same as 1967
1970	All streams 1/1 - 3/31	Altamaha River: Upstream Seaboard RR--Sunday & Monday; Downstream Seaboard RR - Altamaha Park--Saturdays & Sundays All other streams Sunday and Monday	Minimum mesh 4 1/2 in. stretched; other same as 1965	Same as 1967 + Reciprocal Agreement S. C. Savannah River drift nets	Same as 1967
1972	Same as 1970	Same as 1970 Sav. River: New Sav. Bluff Lock and Dam downstream to mouth of Spirit Creek--Sport fishing only	Same as 1970	Same as 1970 except Res. fishermen $5.25 N/R fishermen $100.25	Same as 1967 except license Res. season $3.25 N/R season $10.25 N/R 5-day $3.25
1976	All streams 1/15 - 4/15	Altamaha R.--Upstream Seaboard Coastline RR at Altamaha Park, Glynn County & Ogeechee & Sav. Rivers upstream I-95 Hwy. closed Sun., Mon., and Tues. Altamaha, Ogeechee and Sav. R. downstream these points closed Fri., Sat., and Sun. All others closed Sun., Mon., and Tues. Sav. R., New Bluff Dam & Lock to mouth of Spring Cr. Sport fishing only. Sav. Back R. downstream from New Sav. Cut closed to shad fishing	Same as 1970 + drift nets 100 yds. apart and limited to 1000 ft. length in saltwater but not exceed 2/3 of stream width. Set nets anchored to bank, outer end marked with bouy.	Same as 1972	Same as 1972

Table 3.6-12. Georgia shad regulations (cont'd.).

YEAR	SEASON	CLOSED DAYS AND AREAS	NETS: MESH SIZE & OTHER REGULATIONS	COMMERCIAL (NET) LICENSE	RECREATIONAL OR NON-RECREATIONAL
1977	All streams	Altamaha R. upstream Seaboard Coastline RR Bridge in Glynn County and Ogeechee and Sav. R. upstream I-95 Hwy. closed Sun., Mon., and Tues. Altamaha R., Ogeechee & Sav. River downstream same points closed Sat., Sun., and Mon. All other streams closed Sun., Mon., and Tues.	Same as 1976	Same as 1972	Same as 1972
1979 1980	To be established by the Board of Natural Resources between January 1 and April 31 each year Season closed from May 1 through December 31 of each year.	To be established by the Board of Natural Resources.	To be established by the Board of Natural Resources.	Commercial fishing licenses required. Commercial freshwater fishing license required in freshwaters ($10.25 resident, and $100.25 non-resident). Commercial saltwater fishing license required in the saltwaters of the state ($2.00 resident and $5.00 non-resident). In addition a Georgia Commercial fishing boat license is required ($5.00 for the first 18' of overall length and 50¢ for each foot or fraction thereof for residents and an additional $25.00 fee for non-residents.	Resident shad sport-fishermen must possess a Georgia freshwater fishing license ($3.25); non-residents must possess either a 5 day non-resident sport fishing license ($3.25) or a seasonal non-resident sport fishing license ($10.25). Limits are 8 shad/day and fishermen are limited to two poles and lines each. Bow nets are allowed with a sport fishing license (minimum stretched mesh of 3½ inches).

TRENT RIVER - The fishery is limited by access points above Pollocksville, with bridges serving as major fishing areas - SR 1129 bridge, SR 1130 bridge, and Hwy 58 bridge (Marshall 1977).

CAPE FEAR RIVER - The primary sportfishing area for shad in North Carolina is the Cape Fear River below Lock and Dam No. 1. Anchor gill nets are set in oxbows where the current is slower than the main channel (Fischer 1980).

ST. JOHNS RIVER - Adult shad are harvested by drift nets near the river mouth and haul seines are used in the region between Palatka and Lake George (McLane 1955).

Refer to Tables 3.6-11 and 3.6-12 for review of South Carolina and Georgia fishing areas.

3.6.12.3 Fishing Seasons

NORTH CAROLINA - There are no mandated seasons for American shad, although fishing occurs principally during January through April (M.W. Street 1981, pers. comm.).

SOUTH CAROLINA - Seasons vary with river system and county (Table 3.6-11).

GEORGIA - Seasons are open and closed by the Board of Natural Resources. Seasons for each year are established on a yearly basis between 1 January and 31 April. Shad season is closed from 1 May through 31 December each year (Table 3.6-12).

FLORIDA - No information available.

3.6.12.4 Effort

NORTH CAROLINA - Commercial landings of American shad declined sharply after reaching a peak of nine million pounds in 1897 and have remained low since the turn of the century (Table 3.6-13). Since 1939, American shad landings have comprised less than one percent of the total finfish landed in North Carolina waters (Table 3.6-14). Dockside value reached a peak in 1952, bringing $377,000 for almost nine percent of the total value of finfish landed in that year (Table 3.6-15, Table 3.6-16). By 1979, shad landings comprised only 0.08% of the total finfish landed and contributed less than one percent of the total finfish value. Following is a

breakdown of recreational fishing effort by special devices in North Carolina waters for 1967-68:

ALBEMARLE - 912 fishermen, 3526 trips, 90 shad.
CHOWAN - 1109 fishermen, 5510 trips, 1837 shad.
LUMBER - 11 fishermen, 21 trips, 25 shad.
NEUSE - 2164 fishermen, 19146 trips, 75098 shad.
PAMLICO - 756 fishermen, 5678 trips, 6670 shad.
ROANOKE - 1106 fishermen, 7092 trips, 2069 shad.
TAR - 1493 fishermen, 15068 trips, 28017 shad.
CAPE FEAR SYSTEM - 571 fishermen, 4800 trips, 5000 shad.
NORTHEAST CAPE FEAR - 165 fishermen, 2008 trips, 4600 shad.
PEE DEE - 7 fishermen, 25 trips, 394 shad.

Most of these catches were by casting rod and artificial bait (Baker 1968). The recreational catch for shad in the Neuse River averages 20% of the State's total production (Marshall 1977). The gill net (commercial) fishery in Albemarle Sound accounts for approximately 95% of the shad taken in that area, with the remainder captured incidental to the pound net fishery for river herring (alewives and blueback herring)(Loesch et al. 1977).

SOUTH CAROLINA - Commercial landings for American shad peaked in 1889 at 577,000 pounds and dropped to its lowest level of only 24,000 pounds in 1974 (Table 3.6-13). Shad comprise from 0.67 to 4.64% of the total finfish landed commercially in the State, representing 1.81 to 31.4% of total finfish dockside value (Table 3.6-14, 3.6-16).

GEORGIA - Commercial landings of shad in Georgia have remained fairly stable since 1880, exhibiting a peak of over one million pounds in the early 1900s (Table 3.2-13). American shad is the most commercially important anadromous species in Georgia. During the period 1939 to 1975, American shad landings have comprised an average of 33% of the total finfish landed and 56% of the total finfish value. The commercial shad fishery in the Altamaha River in 1967 (set nets and gill nets) fished 3573 net days and harvested 70,222 American shad and hickory shad weighing 231,733 pounds. The catch consisted of 8.28% female American shad. The catch per standard fishing unit day was 19.6 fish. The population was estimated at 141,928 fish; 48.7% was harvested by the commercial fishery and 72,699 escaped the commercial gear (Godwin and McBay 1967).

TABLE 3.6-13. American shad landed (thousands of pounds).

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA	TOTAL
1880	3221	208	252	.	.	.	.	.	3681
1887	4783	365	256	.	.	.	.	.	5404
1888	5725	433	263	.	.	.	.	.	6421
1889	5403	577	356	.	.	.	.	.	6336
1890	5815	563	400	.	.	.	.	.	6778
1897	8963	506	788	.	.	.	.	.	10257
1902	6567	434	1029	.	.	.	.	.	8030
1908	3942	464	1333	3	.	.	.	.	5742
1918	1657	157	101	.	.	.	.	.	1915
1923	2370	184	134	.	.	.	.	.	2688
1927	2387	182	187	.	.	.	.	.	2756
1928	3118	320	317	.	.	.	.	.	3755
1929	1913	260	472	.	.	.	.	.	2645
1930	1172	214	275	.	.	.	.	.	1661
1931	883	152	132	.	.	.	.	.	1167
1932	925	123	288	.	.	.	.	.	1336
1934	1274	209	232	.	.	.	.	.	1715
1936	1095	177	236	.	.	.	.	.	1508
1937	698	138	193	.	.	.	.	.	1029
1938	1032	59	98	.	.	.	.	.	1189
1939	859	42	75	254	.	.	.	.	1230
1940	801	50	150	344	.	.	.	.	1345
1945	912	89	222	842	.	.	.	.	2065
1950	1100	73	179	298	.	.	.	.	1650
1951	1245	96	206	336	0	.	.	.	1883
1952	1479	135	243	203	.	.	.	.	2061
1953	1188	110	214	124	.	.	.	.	1636
1954	1445	197	180	281	.	.	.	.	2103
1955	649	88	158	508	.	.	.	.	1403
1956	773	116	168	376	.	.	.	.	1433
1957	837	80	247	361	1	.	.	.	1526
1958	493	71	319	589	5	.	.	.	1477
1959	419	80	391	540	.	.	.	.	1430
1960	507	106	533	468	.	.	.	.	1614
1961	673	110	404	425	.	.	.	.	1612
1962	765	115	527	760	.	.	.	.	2167
1963	693	120	331	590	.	.	.	.	1734
1964	640	120	314	613	.	.	.	.	1687
1965	1069	176	376	758	.	.	.	.	2379
1966	701	119	386	.	.	.	.	.	1206
1967	.	.	.	319	.	.	.	.	319
1968	842	110	569	531	.	.	.	.	2052
1969	719	177	618	390	.	.	.	.	1904
1970	953	148	532	218	.	.	.	.	1851
1971	680	99	420	253	.	.	.	.	1452
1972	458	159	344	120	.	.	.	.	1091
1973	321	26	239	99	.	.	.	.	685
1974	369	24	162	100	12	.	.	.	667
1975	241	62	182	33	5	.	.	.	523
1976	167	32	93	.	.	.	.	.	.
1977	121	80	118	.	.	.	.	.	.
1978	422	287	172	.	.	.	.	.	.
1979	278	197	.	.	.	.	.	.	.
1980	199	270	.	.	.	.	.	.	.

Table 3.6-14. Pounds landed (%) of American shad in the total commercial catch of finfish by state.

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA
1880	.	.	.	.	.	.	.	.
1887	.	.	.	.	.	.	.	.
1888	.	.	.	.	.	.	.	.
1889	.	.	.	.	.	.	.	.
1890	.	.	.	.	.	.	.	.
1897	.	.	.	.	.	.	.	.
1902	.	.	.	.	.	.	.	.
1908	.	.	.	.	.	.	.	.
1918	.	.	.	.	.	.	.	.
1923	.	.	.	.	.	.	.	.
1927	.	.	.	.	.	.	.	.
1928	.	.	.	.	.	.	.	.
1929	.	.	.	.	.	.	.	.
1930	.	.	.	.	.	.	.	.
1931	.	.	.	.	.	.	.	.
1932	.	.	.	.	.	.	.	.
1934	.	.	.	.	.	.	.	.
1936	.	.	.	.	.	.	.	.
1937	.	.	.	.	.	.	.	.
1938	.	.	.	.	.	.	.	.
1939	0.40	3.29	2.22	0.14	.	.	.	.
1940	0.50	3.81	20.78	0.20	.	.	.	.
1945	0.51	2.94	18.86	0.38	.	.	.	.
1950	0.71	2.68	20.98	0.73	.	.	.	.
1951	0.90	0.98	25.21	0.33	0.00	.	.	.
1952	0.66	1.87	30.15	0.14	.	.	.	.
1953	0.72	3.33	27.02	0.14	.	.	.	.
1954	0.75	3.60	21.25	0.45	.	.	.	.
1955	0.31	0.96	16.74	0.85	.	.	.	.
1956	0.27	1.38	23.90	0.40	.	.	.	.
1957	0.39	0.65	26.56	0.85	0.00	.	.	.
1958	0.18	1.77	32.22	1.69	0.01	.	.	.
1959	0.13	0.88	36.82	0.78	.	.	.	.
1960	0.21	1.65	34.01	1.00	.	.	.	.
1961	0.25	1.37	32.29	0.70	.	.	.	.
1962	0.47	1.61	50.46	1.19	.	.	.	.
1963	0.30	1.70	40.02	1.04	.	.	.	.
1964	0.31	1.71	46.80	1.38	.	.	.	.
1965	0.53	1.85	40.34	1.21	.	.	.	.
1966	0.31	1.13	47.60	.	.	.	.	.
1967	.	.	.	0.42	.	.	.	.
1968	0.41	1.22	64.73	0.93	.	.	.	.
1969	0.38	3.20	66.31	0.80	.	.	.	.
1970	0.66	4.64	49.61	0.36	.	.	.	.
1971	0.57	2.07	43.12	0.46	.	.	.	.
1972	0.30	3.05	32.00	0.22	.	.	.	.
1973	0.27	0.67	28.42	0.19	.	.	.	.
1974	0.20	0.87	22.25	0.23	0.02	.	.	.
1975	0.11	1.73	24.23	0.07	0.01	.	.	.
1976	0.08	.	.	.	.	.	.	.
1977	0.05	.	.	.	.	.	.	.
1978	0.15	.	.	.	.	.	.	.
1979	0.08	.	.	.	.	.	.	.
1980	0.00	.	.	.	.	.	.	.

Table 3.6-15 Dockside value of American shad (thousands of dollars).

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA	TOTAL
1939	137	8	15	23	.	.	.	.	183
1940	120	11	30	29	.	.	.	.	190
1945	199	31	66	126	.	.	.	.	422
1950	340	23	55	43	.	.	.	.	407
1951	300	43	73	54	0	.	.	.	470
1952	377	41	82	35	.	.	.	.	535
1953	293	32	78	25	.	.	.	.	428
1954	258	55	73	42	.	.	.	.	428
1955	160	27	48	61	.	.	.	.	296
1956	193	41	50	45	.	.	.	.	329
1957	209	25	74	47	1	.	.	.	356
1958	123	23	96	65	1	.	.	.	308
1959	105	26	121	65	.	.	.	.	317
1960	127	34	176	61	.	.	.	.	398
1961	168	35	93	70	.	.	.	.	366
1962	191	32	132	81	.	.	.	.	436
1963	168	33	88	63	.	.	.	.	352
1964	127	28	100	60	.	.	.	.	315
1965	214	61	127	82	.	.	.	.	484
1966	170	34	100	.	.	.	.	.	304
1967	.	.	.	52	.	.	.	.	52
1968	128	21	139	96	.	.	.	.	384
1969	137	59	182	61	.	.	.	.	439
1970	193	39	140	43	.	.	.	.	415
1971	117	40	133	50	.	.	.	.	340
1972	112	45	112	27	.	.	.	.	296
1973	85	12	91	27	.	.	.	.	215
1974	106	12	63	24	1	.	.	.	206
1975	83	37	99	9	1	.	.	.	229
1976	65	20	57	.	.	.	.	.	.
1977	55	54	84	.	.	.	.	.	.
1978	145	197	113	.	.	.	.	.	.
1979	122	155	.	.	.	.	.	.	.
1980	88	214	.	.	.	.	.	.	.

Table 3.6-16. Dockside value (%) of American shad in the total commercial catch of finfish by State.

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA
1939	9.01	15.38	39.47	1.33	.	.	.	.
1940	7.92	19.64	69.77	0.83	.	.	.	.
1945	5.33	10.26	50.77	1.01	.	.	.	.
1950	9.06	10.80	42.42	1.84	.	.	.	.
1951	9.33	6.39	48.67	1.42	0.00	.	.	.
1952	8.98	13.06	53.59	0.61	.	.	.	.
1953	8.21	18.18	51.32	0.68	.	.	.	.
1954	6.08	31.40	44.68	1.22	.	.	.	.
1955	4.02	8.16	37.50	1.87	.	.	.	.
1956	3.56	7.85	48.08	1.30	.	.	.	.
1957	4.57	4.89	55.22	1.34	0.02	.	.	.
1958	2.18	7.57	71.11	2.14	0.02	.	.	.
1959	2.03	7.65	73.33	2.08	.	.	.	.
1960	3.29	8.81	73.33	2.06	.	.	.	.
1961	3.88	4.93	62.00	1.83	.	.	.	.
1962	5.73	5.11	77.19	1.97	.	.	.	.
1963	3.83	5.60	66.17	1.61	.	.	.	.
1964	2.81	3.92	74.63	1.62	.	.	.	.
1965	4.23	6.12	65.80	1.74	.	.	.	.
1966	3.39	5.16	64.94	.	.	.	.	.
1967	.	.	.	0.96	.	.	.	.
1968	2.78	3.65	74.33	1.60	.	.	.	.
1969	2.71	10.73	74.90	1.04	.	.	.	.
1970	4.22	10.05	62.78	0.67	.	.	.	.
1971	2.67	7.46	51.15	0.70	.	.	.	.
1972	1.93	6.27	40.14	0.38	.	.	.	.
1973	0.99	1.81	37.76	0.30	.	.	.	.
1974	1.01	2.44	25.61	0.27	0.00	.	.	.
1975	0.67	5.88	35.61	0.09	0.00	.	.	.
1976	0.44	.	.	.	.	.	.	.
1977	0.34	.	.	.	.	.	.	.
1978	0.59	.	.	.	.	.	.	.
1979	0.37	.	.	.	.	.	.	.
1980	0.25	.	.	.	.	.	.	.

FLORIDA - Commercial catch statistics indicate that the commercial fishery for American shad has never contributed more than two percent of the total finfish landings or more than 2.14% of the total finfish value since 1939 (Tables 3.6-14, 3.6-16). Production of the commercial and sport fishery has declined in the St. Johns River in recent years. Some evidence indicates overfishing, especially for female shad (Williams and Bruger 1972). In 1965, 825,860 pounds were landed, a 50% decrease over the previous five-year average. The sport catch was 132,860 in 32,855 man-days of fishing. South of Lake Harney, 51,255 shad were caught in 7402 man-days of fishing, representing a 200% increase in catch and a two-fish-per-man-day-fishing increased compared to 1964 (Cheek 1966). The commercial fishery landed 322,240 pounds of shad by gill net (Mayport-Jacksonville) and 503,620 pounds by haul seine (Welaka-Palatka-Georgetown area), for a fishing rate of 22% (Cheek 1966).

3.6.13 Protection and Management

3.6.13.1 North Carolina

Sholar (1977a) summarized the present status and future of the North American shad stock:

"The adult shad runs in North Carolina are only remnants of what they were in the past. Landings have fallen precipitously from a peak of nine million pounds in 1897 to a low of about 167,000 pounds in 1976. However, shad landings are considered to be inaccurate due to the decrease in the number of truly commercial shad fishermen in recent years. A large quantity of shad are caught in North Carolina by recreational fishermen using commercial gear. These fish are kept for personal consumption or are 'peddled' to friends; in either case they never enter official statistics. The lack of catch-effort data for the fishery also prohibits a true picture of the shad resource. Even with these inadequacies, the trend is the same; fewer fish are being caught each year. Currently there are insufficient data to determine the actual cause or causes for decline."

3.6.13.2 South Carolina

Ulrich et al. (1979) summarized present management and protection practices for South Carolina:

"In South Carolina, most anadromous fish regulations are set by legislative action. The (Wildlife and Marine Resources) Department may submit proposed legislation which must be approved by the Marine Advisory Board (or the Wildlife and Freshwater Fisheries Advisory Board) and the South Carolina Wildlife and Marine Resources Commission. The Commission is the governing board of the Department and is composed of nine members, two of whom are the chairman of the Agriculture and Natural Resources Committee of the State House of Representatives and the Fish, Game, and Forestry Committee of the State Senate. If the legislative package is approved, it is then submitted to the aforementioned committees. These committees then decide whether to release the legislation for voting. However, in most cases, new legislation is proposed by members of a county delegation. A county delegation is composed of the legislators from a particular county. Any member or members of the delegation can introduce proposed legislation which he feels is necessary, into either the House or the Senate, depending on in which he is a member. The legislation is then referred to the appropriate committee. Through a legislative liason, the Department may request a copy of the proposed legislation, make any changes it deems necessary, and resubmit it to the committee. The committee may or may not retain the suggested changes and decides whether to release the legislation to the floor of the General Assembly for a vote.

"The Department may establish rules and regulations not contrary to legislation through the State Register procedure. The Department must give public notice that it will create a rule or regulation. There is a 45-day waiting period between the time the public notice is given and the time it can be filed with the legislature. The legislature is then given 90 days within which it may act. If legislature approval or disapproval is not forthcoming during that period, the regulation becomes effective. If there are not 90 days left in the legislative session once a regulation is filed, it must be actively approved or carried over until the next session."

Ulrich et al. (1979) also identified basic problems in attempting to manage South Carolina shad stocks effectively. The most basic problem concerns the inadequacy of the present data base for assessing the conditions of the stocks. Historically, shad landings were collected from dealers buying and shipping

to northern markets, and no records were collected from small retail fish markets, crossroad grocery stores, and small roadside stands. Additionally, recreational fishery statistics on the number of participants and the catch are lacking. Catch-per-unit-effort data are generally unavailable; in the instances when CPUE data has been calculated, it has been for limited time periods or areas and has not been comparable with previous studies. The population dynamics of anadromous species are not well-known. Up-to-date shad licensing data is very difficult to obtain. One of the biggest management problems is the lack of broad regulatory powers and inability to make timely decisions relating to anadromous species.

Interviews with enforcement officers by Ulrich et al. (1979) indicated a need for uniform statutes throughout the State. The expected benefits of uniform laws would include increased clarity for the fishermen, improved law enforcement efficiency, and generally more equitable statues. Some officers felt that statutes needed to be oriented toward river systems and not game zones in order to minimize boundary area confusion.

Certain areas in South Carolina are closed to commercial shad fishing or the setting of any nets. No restricted areas are designated for recreational shad fishing. Shad gill nets are prohibited in the Cooper River above the confluence of the East and West branch, in the Savannah River from the mouth of Spirit Creek upstream to the New Savannah Bluff Lock and Dam, on the Combahee River from U.S. Hwy 17 seaward, and within three miles of the Winyah Bay jetties. In addition, shad nets may not be set in lakes or coves tributary to any stream or in the muddy waters of any river within 25 years of the mouth of a clear water stream (Ulrich et al. 1979).

3.6.13.3 Georgia

The Board of Natural Resources has the power to set seasons, gear restrictions, and other regulations pertaining to anadromous fisheries. Certain areas are closed to commercial shad fishing, and no restricted areas are designated for recreational shad fishing. Shad fishing with nets is prohibited in the Savannah River system in Back River, downstream from New Savannah Cut. Shad nets may not be set in coves or tributaries of a river or within 0.5 mile below any lock or dam (Ulrich et al. 1979).

Management problems and current status of American shad in Georgia were summarized by Michaels (1980):

"Three major problems of resource allocation have been identified by shad fishermen. The first two deal with conflicts between inland and coastal commercial fishermen. The third problem deals with the recreational fishermen's concern. Upstream commercial fishermen complain that they are denied a fair share of the catch because of the intensive fishery in the lower coastal waters. They desire a longer season so that more shad can be caught inland. Downstream fishermen are primarily concerned with opening the season earlier so that they can catch shad when prices are the highest. Recreational fishermen are concerned that their fishery is adversely affected by commercial interests (Ulrich et al. 1979).

"The management and regulation of Georgia's shad fishery to provide optimum economic and recreational benefits have been ineffective for many years. Regulations have been changed frequently in an attempt to stabilize the fishery (Godwin and McBay 1967). The Altamaha River, for example, has had a three month commercial season for many years but various opening and closing dates. The most recent shad season opened 17 January 1980 and closed 15 April 1980. Five open days each week were allowed from 1970 to 1972. Only four open days each week were permitted in 1976 and 1977. The 1980 season returned to two closed days each week. Methods for taking shad have not changed drastically over the past 10 years. Minimum mesh size for both drift and set nets has been 4½ inches stretched. Length of set and drift nets has been limited to 150 and 1,000 feet, respectively. One major change has been the stream width left open for the passage of fish. In 1980 nets were to be situated so as to allow one-half the stream width to remain open. In previous years only one-third of the width was required to be free of nets.

"These regulations, however, have been made without sound biological data to support them. One basic problem in estimating fishing effort has been acquiring up-to-date licensing data. Due to lack of any automatic processing system, obtaining a complete list of licenses has been extremely difficult. In a study by Ulrich et al. (1979) licensing data for Georgia represented less than 10% of the total license sales. In 1980 the shad license was eliminated in favor of a

commercial freshwater license, making it impossible to determine any distribution of effort or even the number of participants in the shad fishery.

"Landing data are highly questionable. Historically, they have been collected almost exclusively from dealers engaged in buying and shipping to northern markets. A high percentage of the shad caught outside lower coastal reaches of the major rivers is sold through small outlets, often handling more shad than the commercial buyers and shippers (Ulrich et al. 1979). Full-time commercial fishermen depend on their catch as a primary source of income. The bulk of their catch goes to commercial buyers and shippers. Part-time fishermen sell at least a portion of their catch for profit, normally as a supplement to other income. Most of the fish are sold locally to fish and grocery stores. The occasional shad fishermen fish as a source of recreation. Most of their catch is either given away or kept for home consumption. Godwin's (1968) data indicated that of 121 shad fishermen participating in the Altamaha River's coastal fishery, 47.9% fished part-time or occasionally. Thus the total commercial catch has been underestimated, especially with respect to the second and third types of fishermen.

"Even more questionable is the landing data's validity as an indicator of shad abundance. Noted fluctuations in the catch are more indicative of the effort and methods used to collect the statistics than the relative stock size. Due to a lack of prior catch and effort data on the Altamaha River shad fishery, basic parameters such as population size, escapement, and exploitation could not be determined for years previous to 1967 and subsequent to 1968. These parameters are necessary in order to understand the present status of the American shad and to help determine spawning stock abundance in subsequent years. Without this knowledge the shad fishery cannot be effectively managed" (Michaels 1980).

3.6.13.4 Florida

Williams and Bruger (1972) summarized effects of proposed environmental changes on the St. Johns shad population and recommendations for management:

"Production of commercial and sport fisheries has declined in recent years, possibly because of overfishing. Since 1958, there has been a large decrease in the effort of the haul seine fishery with a concomitant increase in effort in the gill net fishery. Reducing the effort of commercial and sport fisheries may be necessary to reverse the downward trend in production.

"Proposed upper river alterations may adversely affect the quality of American shad spawning grounds in the St. Johns. The Central and Southern Florida Flood Control District (FCD) has planned an extensive series of water control structures, levees, canals, and reservoirs to control flooding and prevent extreme low water conditions caused by overdraining the headwater marshes and urban and agricultural encroachment on the flood plain. More than 30 miles of important shad spawning areas will be affected by structures S-158 (a low, fixed crest weir directly south of Lake Harney), S-55 (a water gate for the Lake Poinsett Reservoir), and their associated impoundments; the Lake Washington structure (S-53) and reservoir are above major spawning areas and their effects on shad are considered negligible or minimal. However, if either S-158 or S-55 creates a barrier to shad migration, the resultant decrease in available spawning area will severely threaten the population.

"The interrelated variables to be considered in determining the project's impact include: methods for moving shad past the barriers, water flow in and below the impoundments, and water quality in the reservoirs" (Williams and Bruger 1972).

Williams and Bruger (1972) also cite the proposed St. Johns-Indian River Canal and increased urbanization and industrialization as threats to the quality of shad spawning area in the St. Johns River. Probable effects are: decreased water quality from sewerage and industrial effluents and loss of marshes in the upper river; loss of marshes and floodplain necessary for incubation of shad eggs; increased sediment load due to rapid drainage runoff; decreased water flow due to increased diversion for municipal water supply systems; loss of river bottom to dredging by developers; and increased sportfishing pressure. The future of American shad in the St. Johns will depend on adequate knowledge of its biology so that effective management procedures can be formulated and adverse effects of urbanization and water works can be minimized (Williams and Bruger 1972).

3.6.13.5 Tagging

Conventional fastening with a pigtail loop formed with needle-nose pliers produced two times as many returns as the rivet-type plier, even though the latter greatly reduced the time that the fish were handled (White and Lane 1967).

3.6.13.6 Marking

American shad pelvic-clipped and released in the Connecticut River returned to spawn in three succeeding years. The ages determined from scales were in agreement with the known age at release, thus validating annuli and spawning marks as agers for shad (Judy 1960).

3.6.13.7 Water Release from Dams

Cold water releases from reservoirs may adversely affect spawning and nursery area utilization of American shad downstream (Chittenden 1972b).

3.6.13.8 Fishways

Holyoke Dam (139.4 km above the Connecticut River mouth) is the site of the most effective American shad passage facility on the east coast (1975). River flow and water temperature are the most important factors explaining the variation in daily lift numbers. Shad enter the lift throughout daylight hours, peak shortly after noon, and cease entry with the onset of darkness (Scherer 1975).

3.6.13.9 Locking

American shad spawning runs were cut off in the Cape Fear River in 1915 when the Corps of Engineers built a dam near Wilmington to aid navigation. In 1962, water releases through the lower of the three locks permitted about 1,000 shad to continue their spawning run upriver. In 1966, the second lock upstream near Elizabethtown was opened and in 1967, the third lock was opened to permit some passage of spawning shad. In 1968, more than 20,000 shad passed through the locks and the sport catch increased enough to attract widespread sport fishing interest (Dean 1969).

3.6.13.10 Increased Water Temperatures

Increased average water temperatures in rivers utilized by American shad can be expected to directly influence the migration energetics of the population, causing depletion of energy reserves and increased postspawning mortality (Glebe 1977).

3.6.13.11 Restoration

Extension of the Connecticut River migration to the historical range of the speices in the river will significantly alter the population structure. Shad spawning in areas above existing sites will experience a significantly higher energy cost and proportionally higher postspawning mortality. Thus an increased proportion of virgin shad in the Connecticut River is predicted as the restoration program proceeds (Glebe 1977).

3.6.13.12 Pollution

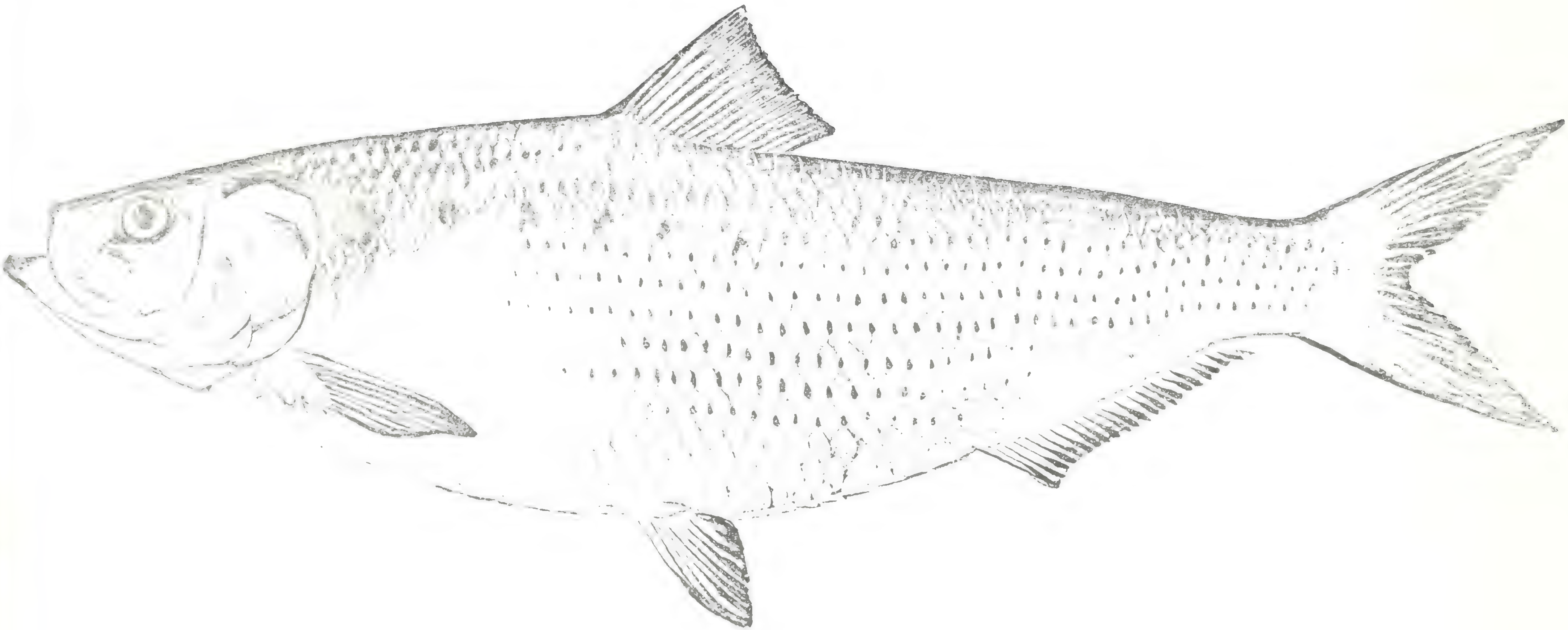
Pollution is the biggest problem affecting shad stocks in the Delaware River. Pollution must be diluted to tolerable levels by maintaining sufficiently high river flows. The Interstate Commission on the Delaware River Basin recommended reducing pollution to three billion gallons per day, a value probably insufficient to insure shad survival (Sykes and Lehman 1957).

3.6.13.13 Water Control Projects

The proposed St. Johns-Indian River Canal and proposed water control projects by Central and Southern Florida Flood Control District may reduce future shad runs by eliminating and/or degrading sections of spawning areas between Lake Monroe and Lake Poinsett (Williams and Bruger 1972). These water developments could eliminate a significant part of the sport fishery for shad south of Lake Harney and use of this section of river as spawning and nursery habitat (Cheek 1966).

Drastic reduction in anadromous fishes in the New River (North Carolina) is probably due to reduced recruitment. Low spawning and juvenile success is probably due to lack of suitable habitat which places the anadromous stocks in serious danger. The future of the New River anadromous population will depend on the ability of the tributaries to provide suitable habitat to maintain recruitment since the habitat previously found in the New River above Jacksonville no longer exists (due to water projects) (Sholar 1975).

The White Oak River (North Carolina) currently supports a small recreational dip net and gill net fishery which appear to have little or no impact upon anadromous fish populations. The greatest threat is flood control projects such as watershed development and channelization (Sholar 1975).



Hickory shad

Alosa mediocris

3.7 Hickory Shad (Alosa mediocris)

3.7.1 Historical Significance

Hickory shad are also known as hick, hickory jack, bone jack, freshwater Tailor (Hildebrand and Schroeder 1928), skip-jack, Tailor herring, Tailor shad, fall herring, shad herring, and fall shad (Ulrich et al. 1979). Hickory shad closely resemble skipjack herring (Alosa chrysochloris) in body form (Williams et al. 1975). It is a palatable food fish but not as choice as American shad (McLane 1955). Hickory shad were important as food fish prior to widespread refrigeration when they were salted and shipped to Northern and Midwestern States (Williams et al. 1975).

3.7.1.1 North Carolina

The hickory shad has always been an important part of North Carolina anadromous fisheries. Although it has not always been sought commercially, it is highly valued as a recreational species (Marshall 1977). Recreational catches far exceed commercial catches in North Carolina (Hawkins 1979). The Neuse River is probably the most popular sport fishing area for hickory shad in the State, particularly the area around Pitchkettle Creek (Marshall 1977). Drift-netting is a socially significant activity on the Neuse River, with large crowds of people from the community and surrounding areas gathering to catch fish and eat (Hawkins 1979). A recreational fishery also exists in the Tar-Pamlico River; special devices used are drift gill nets and hook-and-line (Marshall 1976). In the Albemarle Sound area, recreational fishing for hickory shad occurs in the Chowan, Cashie, and Meherrin Rivers (Street et al. 1975). Area residents report that catches have declined considerably in recent years (Marshall 1977).

Commercial catch statistics show that hickory shad abundance has declined in North Carolina since 1945. The commercial fishery is usually limited to the larger females and exists as part of the more extensive fishery for American shad (Marshall 1977). Gill nets and pound nets accounted for 96.6% of commercial catches from 1960 to 1970 (Chestnut and Davis 1975).

3.7.1.2 South Carolina

There is no commercial or sport fishery specifically for hickory shad in South Carolina, and most are taken incidental to commercial fishing for American shad

(Ulrich et al. 1979). In areas where regulations permit the use of smaller mesh sizes, hickory shad are caught in greater numbers; they are also taken by rod and reel on the same lures used for American shad (Ulrich et al. 1979). In the Santee River, gill netting is conducted primarily for American shad and the capture of smaller hickory shad is coincidental. Hickory shad comprised 17% of the shad harvest in 1972, 16% in 1973, and only eight percent in 1974 (Curtis 1974).

3.7.1.3 Georgia

Hickory shad and American shad have attained commercial significance and have become the most significant commercial finfish fishery on the Georgia coast (Smith 1968, Godwin and Adams 1969). This resource is harvested by 500 to 600 commercial fishermen during the three-month season (Godwin and Adams 1969). Greatest threats to the Georgia fishery are industrial pollution and proposed development of the Altamaha River system (Godwin and Adams 1969).

3.7.1.4 Florida

The hickory shad is common to rivers along the east Florida coast. Migration into coastal rivers occurs about the same time as that for American shad and blueback herring. Historically, hickory shad was commercially important but is seldom used as a food fish today (Williams and Grey 1975). In Florida they are used as bait for catfish and crab fisheries in the St. Johns River (McLane 1955, Williams et al. 1975). Populations of hickory shad are common in the St. Johns and St. Marys Rivers, and populations probably once occurred as far south as Tomoka River, which is a small freshwater tributary of the Halifax River north of Cape Canaveral (Williams and Grey 1975).

Hickory shad have some importance as a game fish since most sport fishermen do not recognize it from American shad (Williams et al. 1975). They are a relatively minor species in the St. Johns River - vastly outnumbered by American shad - and comprise only 2.4% of the "shad" catch among St. Johns sport fishermen (Walburg 1960). Hickory shad is the only species in the St. Johns River that has migrating individuals that are not spawning adults (McLane 1955).

3.7.2 Distribution

3.7.2.1 Range

The hickory shad ranges along the Atlantic coast from the Bay of Fundy to Florida (Bigelow and Schroeder 1953). This species is well-established in the St. Johns and St. Marys Rivers with minor populations in the Nassau and Tomoka Rivers (Williams and Grey 1975). Cape Canaveral is the effective southern limit because the water temperature south of the Cape rises rapidly to become semi-tropical in nature and because suitable spawning habitats are scarce along the south Florida coast (Williams and Grey 1975).

3.7.2.2 Eggs

Hickory shad eggs possibly are broadcast at random, and are semi-demersal in slow-moving waters but buoyant under turbulent conditions (Mansueti 1962). They are adhesive but easily dislodged by currents (Mansueti and Hardy 1967).

3.7.2.3 Larvae

Hickory shad larvae are collected from fresh and brackish rivers and tributaries (Godwin and Adams 1969, Hawkins 1979, Fischer 1980). Larvae are probably carried downstream by the flushing action of tributary waters (Godwin and Adams 1969), but localized habitats and distributions are not known.

3.7.2.4 Juveniles

Juvenile hickory shad are found in fresh and brackish rivers and tributaries (Godwin and Adams 1969, Hawkins 1979, Fischer 1980). Lower portions of estuaries and ocean nearshore areas are possibly utilized as nursery areas, but distributions and nursery areas have not been determined.

3.7.2.5 Adults

Hickory shad is a schooling species. Oceanic distribution is unknown; probably the adults never stray far from land. In North Carolina, the riverine distribution during spawning is often similar to that for American shad (Baker 1968).

3.7.3 Reproduction

3.7.3.1 Maturity

Minimum age at which hickory shad reach maturity appears to be II in some river systems and III in others. Both male and female hickory shad may begin spawning migrations at age II in North Carolina; Pate (1972) found age II males the predominant spawning age class in the Neuse River. Hawkins (1979) reported that both males and females begin spawning in the Neuse River at age III. Two males were captured in the White Oak River, ages III and IV; both were virgin (Sholar 1975). Three hickory shad collected in the Edisto River, South Carolina, were females from age class III and possessed no spawning marks (Wade 1971). Female hickory shad mature earlier than males in the Altamaha River; by age II, 75% of the females and 49% of the males were sexually mature (Street and Adams 1969). Some males (44%) and females (36.7%) in the St. Johns River initially spawned at age II; most spawned at least once by age III and all had spawned by age IV. Males matured slightly earlier than females (Williams et al. 1975).

3.7.3.2 Mating

No information available.

3.7.3.3 Fertilization

Eggs are released in open water areas of rivers where they are fertilized.

3.7.3.4 Fecundity

Females from the Neuse River showed a correlation between fecundity and fork length and weight. Number of eggs per female ranged from 44,556 to 347,610 (Pate 1972). Hickory shad from the Altamaha River showed increased fecundity with age and size; fecundity ranged from 252,693 to 730,213 with a mean of 500,519 eggs per female (Street 1970). Females from the St. Johns River exhibited low correlation between fecundity and weight, length, and age; fecundity ranged from 168,000 to 591,000 with a mean of 363,000 eggs per female (Williams et al. 1975).

3.7.4 Spawning

3.7.4.1 Season and Location

In North Carolina, hickory shad probably spawn between late March and early May (Table 3.7-1) (Pate 1972, Hawkins 1979). Spawning in the New River is very slight and limited to the area below NC Highway 24 by the barrier presented by the culvert under the highway (Table 3.7-2). No larvae were collected in 1975, indicating very poor spawning success (Sholar 1975). No hickory shad eggs or larvae were collected in the White Oak River in 1975 (Sholar 1975). There was little evidence of spawning in the Cape Fear River in 1978 or 1979; three postlarval hickory shad were found above NC Highway 133 bridge in Town Creek (1978) and one at Mile Board 10 in the Cape Fear River (1979) (Fischer 1980). In South Carolina, hickory shad spawn between early March and early May (Bulak and Curtis 1978). In Georgia, spawning occurs from mid-March to late May. The spawning season and location of the spawning grounds for hickory shad in the St. Johns River, Florida, are not known. Based on the collection of three small juveniles (19.6 to 34.0 mm) between Lake Monroe and Lake George in February and March 1973, it is likely that at least part of their spawning area is south of Lake George. Sexually mature hickory shad are commonly caught by sportfishermen south of Lake Monroe (Williams et al. 1975).

3.7.4.2 Temperature

Hickory shad eggs have been collected in waters ranging in temperature from 9.5 C (Pate 1972) to 22 C (Street 1970). Temperatures at which eggs were collected in specific river systems are:

ALBEMARLE AREA - 13 to 21 C (Street et al. 1975).
TAR RIVER - 14 to 19 C (Marshall 1976).
NEUSE RIVER - lowest 9.5 C (Pate 1972); range 13 to 18.5 C (Hawkins 1979).
COOPER RIVER - peak catch 10 to 14 C (Bulak and Curtis 1978).
ALTAMAHA RIVER - 15 to 22 C (Street 1970).

3.7.4.3 Spawning Habitat

The spawning habitat of hickory shad has not been determined. River swamp areas, lakes, and larger tributaries may be utilized (Godwin and Adams 1969, Street 1970).

Table 3.7-1. Spawning season of hickory shad.

RIVER SYSTEM	SEASON	SOURCE(S)
Tar River	Late March to early April	Marshall (1976)
Neuse River and tributaries	Late March to early May	Pate (1972) Hawkins (1979)
New River	Probably May	Sholar (1975)
White Oak River	Not known	Sholar (1975)
Santee River	2 eggs collected between April and mid-May	Bulak and Curtis (1978)
Cooper River	Early March to early May; peak egg catch 11-25 March	Bulak and Curtis (1978)
Altamaha River	Mid-March to late May	Godwin and Adams (1969) Street (1970)
St. Johns River	Not known	Williams et al.(1975)

Table 3.7-2. Spawning grounds of hickory shad.

RIVER SYSTEM	LOCATION	SOURCE(S)
Neuse River	River Mile 80 to 97 and tributaries:	Hawkins (1979)
Turkey Quarter Cr.	Entire creek	
Pitchkettle Cr.	Entire creek	
Taylor Cr.	Entire creek	
Halfmoon Cr.	Entire creek	
Contentnea Cr.	Entire creek	
Grindle Cr.		Pate (1972)
Chowan River	Upper Chowan into the Nottoway and Meherrin Rivers above the Virginia border	Marshall (1977)
Roanoke River	From mouth to River Mile 105	Marshall (1977)
Tar River	River Mile 60 to 121 (between) Rocky Mount and Greenville)	Marshall (1977)
New River	Just below NC Highway 24	Sholar (1975)
White Oak River	Not known	Sholar (1975)
Cape Fear River	Not known	Sholar (1977b) Fischer (1980)
Northeast Cape Fear River	Not known	Sholar (1977b) Fischer (1980)
Cooper River	Above River Mile 72; abundance of eggs collected: Tailrace Canal, 51.9%; Berkeley Country Club, 36.8%; Pamlico, 3.8%; Mouth West Branch, 6.6%; Mouth East Branch 0.9%	Bulak and Curtis (1978)
Altamaha River	Not in main river; from River Mile 20 to 137 in lakes, tributaries and river swamp areas	Godwin and Adams (1969) Street (1970)
St. Johns River	Not known; possibly south of Lake George	Williams et al. (1975)

3.7.4.4 Diel Spawning Patterns

Most spawning probably occurs from dusk to midnight (Mansueti and Hardy 1967).

3.7.5 Life History - Eggs and Larvae

3.7.5.1 Hatching and Growth

Fertilized hickory shad eggs are transparent and spherical with a diameter of 0.96 to 1.65 mm (Mansueti and Hardy 1967). Incubation time ranges from 48 to 70 hours at 16 to 31 C (Mansueti and Hardy 1967).

GROWTH - Hickory shad larvae average 6.1 mm TL at hatching (Mansueti 1962). The yolk-sac is absorbed in four to five days at an average length of 6.8 mm. Larvae become juveniles at 35 mm TL (Ulrich et al. 1979).

FEEDING - No information available.

METABOLISM - No information available.

3.7.5.2 Hardiness

SALINITY - No information available.

TEMPERATURE - No information available.

SALINITY-TEMPERATURE INTERACTION - No information available.

ACCLIMATION - No information available.

OXYGEN - Eggs in the Neuse River were collected in water with an oxygen content of 5 to 10 ppm (Hawkins 1979).

SUSPENDED SEDIMENTS - No information available.

pH - Eggs in the Neuse River were collected in waters ranging from pH 6.4 to 6.5 (Hawkins 1979). Some eggs and larvae in the Altamaha River were collected at minimum pH levels (Street 1970).

TRANSPORT - No information available.

3.7.5.3 Swimming Ability

The swimming ability of hickory shad larvae has not been determined.

3.7.5.4 Chemical Tolerances

The tolerance of larvae to chemicals is not known.

3.7.5.5 Pressure

Pressure effects on hickory shad larvae are not known.

3.7.6 Life History - Juveniles

3.7.6.1 Nutrition and Growth

The inability of investigators to locate nursery grounds and determine distribution patterns of juvenile hickory shad has caused major gaps in information concerning food habits and growth patterns.

FEEDING - No information available.

GROWTH - Juveniles in the Neuse River reach 37 to 55 mm by June (Hawkins 1979) and are 85 to 90 mm in the lower Neuse by July and August (Spitsbergen and Wolff 1974). Cape Fear River juveniles range from 31 to 55 mm FL in June and July (Fischer 1980). Juveniles are collected only in June in the Northeast Cape Fear River; they ranged from 23 to 45 mm with a mean of 30 mm FL in 1976 (Sholar 1977b). Juveniles had mean lengths of 35 mm in 1977 and 39 mm in 1978 (Fischer 1980). Juveniles in the Waccamaw and Pee Dee Rivers grew from 63 to 135 mm TL and 2.1 to 20.3 g during July through October 1974 (Crochet et al. 1976). Altamaha River hickory shad increased from 10 mm larvae in April to 140 mm juveniles by December, a faster growth rate than that observed for blueback herring or American shad juveniles (Street 1970). Growth is fast June through August and then becomes considerably slower (Street 1970). During July through October 1968, juvenile size increased from 70 to 114 mm FL and 4.54 to 22.63 g (Smith 1968). Juveniles in the St. Johns River grow faster than blueback herring or American shad juveniles, becoming as large as 92 to 99 mm by late July and perhaps exceeding 200 mm by December (Williams et al. 1975). Three subadult hickory shad captured in the St. Johns River measured 211 to 228 mm and were nearly one year old (Williams et al. 1975).

METABOLISM - Juvenile hickory shad metabolism has not been determined.

3.7.6.2 Hardiness

SALINITY - Juvenile hickory shad were found in the Altamaha River during the summer from the estuarine river section up to 10% salinity; in August and December, they were captured in salinities ranging from 10 to 20 $^{o}/oo$ (Street 1970).

No information was available concerning the hardiness of juvenile hickory shad to the following variables: temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport.

3.7.6.3 Swimming Ability

Juvenile swimming ability is not known.

3.7.6.4 Chemical Tolerances

Juvenile tolerance to chemicals has not been determined.

3.7.6.5 Pressure

Effects of pressure on juvenile hickory shad are not known.

3.7.7 Life History - Adults

3.7.7.1 Longevity

Little information is available on the average life expectancy of hickory shad in Southeast waters. Commercial exploitation may reduce the average life expectancy of stocks, especially if populations are overfished. Marshall (1977) reported males and females, age class VIII, were collected in the Neuse River in 1977, and Hawkins (1979) reported age VII as the oldest group in 1978. Street and Adams (1969) reported age VII hickory shad were collected from the Altamaha River. The Northeast Cape Fear River stocks dropped from a maximum age of VI for both sexes in 1975 (Sholar 1977b) to age V for both sexes in 1979 (Fischer 1980).

3.7.7.2 Nutrition and Growth

FEEDING - Adult hickory shad are primarily piscivorous but will also consume squid, fish eggs, small crabs, and various pelagic crustaceans (Hildebrand and Schroeder 1928). Pate (1972) reported adults do not feed during the freshwater migration. Adults in the

St. Johns River actively feed, with 62.4% of the food items consisting of fish (Williams et al. 1975). Principal food items were: Atherinidae, 15.9%; Engraulidae, 4.4%; Clupeidae, 11.6%; Cyprinidae, 2.9%; unidentified fish, 24.6%; fish remains, 17.4%; Decapoda, 2.9%; debris, 10.1%; and empty stomachs, 24.6% (Williams et al. 1975).

GROWTH - Hickory shad grow rapidly during the first two years of life and then growth increments decrease with age (Pate 1972). In North Carolina, the growth rate of the first year was 68.7% of total growth; proportion of total growth was 22.4% the second year, 8.4% the third year, 4.1% the fourth year, 3.0% the fifth year, 2.8% the sixth year, 1.4% the seventh year, and 0.5% the eighth year (Pate 1972). Maximum length is 600 mm (Hildebrand 1963). The observed and backcalculated fork lengths for adult hickory shad in the St. Johns River roughly coincide with one another but there is a tendency for "backcalculated lengths" to exceed "lengths at capture" (Williams et al 1975). The fork length - weight relationship for St. Johns River hickory shad was estimated as

Females $W = 1.7871 \times 10^{-6} L^{3.373}$ or

$$\mathrm{Log}_{10} W = -5.748 + 3.373\ \mathrm{Log}_{10} L$$

Males $W = 3.9084 \times 10^{-6} L^{3.230}$ or

$$\mathrm{Log}_{10} W = -5.408 + 3.230\ \mathrm{Log}_{10} L$$

(Williams et al. 1975).

METABOLISM - Body tissue of hickory shad in the Altamaha River contained 3.0 to 12.9% fat. Fat content did not decrease with distance upstream, probably due to the relatively short and easy passage. A likely decrease in fat content with the act of spawning was not demonstrated due to a small sample size; condition factor was not consistently related to fat content (Perkins and Dahlberg 1971).

3.7.7.3 Hardiness

SALINITY - The upstream limit for adults in the St. Johns River is in the region from Big Lake George southward to include the Salt-Loughnam-Ruth Lake region of the Puzzle Lake section; salinity ranges from 200 to 10,700 ppm in this area (McLane 1955).

TEMPERATURE - No information available.

SALINITY-TEMPERATURE INTERACTION - No information available.

ACCLIMATION - No information available.

OXYGEN - No information available.

SUSPENDED SEDIMENTS - No information available.

pH - Adult hickory shad are collected at the minimum pH levels in the Altamaha River (Street 1970).

TRANSPORT - No information available.

3.7.7.4 Swimming Ability

The swimming ability of adult hickory shad is not known.

3.7.7.5 Chemical Tolerances

Adult tolerances to chemicals have not been determined.

3.7.7.6 Pressure

Pressure effects on adult hickory shad are not known.

3.7.8 Behavior

3.7.8.1 Juvenile Migration and Local Movement

VIRGINIA - Juveniles remain in freshwater until the temperature drops in October and November, moving further downstream as fall progresses (Davis 1973).

NORTH CAROLINA - Juveniles spend only a short time in upstream areas of the Neuse River before migrating to high salinity tributaries of the lower Neuse and Pamlico Sound (Pate 1972, Marshall 1977). Migration in the Neuse River may begin in June (Marshall 1977); no juveniles were collected in May by Hawkins (1979) and only four fish were captured in June. Juvenile hickory shad were collected in the lower Neuse River in July and August of 1973 (Spitsbergen and Wolff 1974). In the Cape Fear River, juveniles were captured only in June 1976 below NC Highway 53, above Burgaw Creek, and at River Km 3, indicating migration out of the river to possible offshore nursery areas (Sholar 1977b). Juveniles were

also captured in June or July in years 1977 through 1979 from the area above Interstate 95 near Fayetteville (River Mile 115) to Town Creek below Wilmington; young hickory shad probably migrate out of the Cape Fear River system in June or early July (Fischer 1980). Juveniles in the Northeast Cape Fear River were only collected in June 1977 and 1978 (Fischer 1980).

SOUTH CAROLINA - Juvenile hickory shad descend the Pee Dee and Waccamaw Rivers much earlier than young American shad, and by July the major area of abundance is Winyah Bay. They remain in the bay throughout their first summer, then enter the ocean in early fall; greatest abundance occurs in August (Crochet et al. 1976).

GEORGIA - In the Altamaha River, there is a general downstream drift of larval hickory shad which apparently disperse throughout the river system after reaching a sufficient size (Godwin and Adams 1969). Juveniles enter the estuarine area in late spring (Street 1970). By June, all hickory shad are captured in the estuary but comprise only 0.33% of the total catch (Smith 1968). The primary nursery area is not well-defined. Smith (1968) stated that the estuary was probably the nursery zone; however, Godwin and Adams (1969) and Street (1970) suggested that juveniles move to shallow offshore areas near the river mouth and then disperse further by August and September.

FLORIDA - The distribution and local movement of juvenile hickory shad in the St. Johns River is not known. The only three fish collected in February and March 1973 were taken between Blue Springs and the south end of Lake George, presumably migrating from the (unknown) nursery grounds. In April 1969, a juvenile was captured near Mayport about 4 km from the river mouth suggesting a very rapid downstream migration. However, one fish captured on 21 June 1969 and three collected on 29 July 1969 were 102 to 111 km upstream still in freshwater (Williams et al. 1975).

3.7.8.2 Adult Migration and Local Movement

Adult hickory shad habitats are unknown (Street 1970). The length of time adults remain in freshwater after spawning is unknown; hypothetically, they gradually move downstream and return to the ocean by mid-summer (Street 1970). Some of the special devices utilized by commercial fishermen are not conducive to the capture of adult hickory shad, and those collected are many times mistaken for American shad.

Offshore movements are virtually unknown.

OFFSHORE NORTH CAROLINA - Catches of hickory shad from offshore North Carolina have been very low. Adults were collected sporadically during November through March mainly in the area north of Cape Hatteras in less than ten fathoms of water (Holland and Yelverton 1973).

WHITE OAK RIVER - An adult male was captured in January (1974) and another in May (1975)(Sholar 1975).

NEUSE RIVER - Adults are taken mainly in gill nets during late February and early March at temperatures of 5 to 15 C (Hawkins 1979). Two tagged adults out two to five days were recaptured 29 and 50 km downstream. A third was recaptured after 31 days 22 km upstream, indicating that hickory shad may rapidly move downstream in the Neuse River after tagging and then return upstream to possible spawning areas (Hawkins 1979). Marshall (1977) reported similar results.

NORTHEAST CAPE FEAR RIVER - Peak catches for adults occurred in late March and early April in 1976 (Sholar 1977b) and at similar times in 1978 and 1979 (Fischer 1980).

ST. JOHNS RIVER - Hickory shad are the earliest migrants into the St. Johns River; they were already present in December and were the first absent in mid to late February 1972 and late January 1973 (Williams et al. 1975). They are found upstream as far as Lake Harney November through March (McLane 1955).

3.7.8.3 Responses to Stimuli

No information available.

3.7.9 Population

3.7.9.1 Sex Ratio

There is no information on the sex ratio for the total population along the Southeast U.S. coast. The male:female sex ratio for the Northeast Cape Fear River was 1.5:1 in 1976 (Sholar 1977b), 3.25:1 in 1978, and 2.3:1 in 1979 (Fischer 1980). Pate (1972) reported the male:female ratio in the Neuse River was 4:1.

3.7.9.2 Age Composition

WHITE OAK RIVER - One age III male was captured in January 1974 and one age IV male was captured in May 1975 (Sholar 1975).

NEUSE RIVER - Ages ranged from III to VII (Table 3.7-3) for both males and females; males were most abundant at age IV and females predominated at ages IV and V (Hawkins 1979). No age II hickory shad and few age III males were captured during Hawkins study but were reported by Pate (1972) and Marshall (1977).

NORTHEAST CAPE FEAR RIVER - In 1976, hickory shad ranged in age from III to VI years; males were dominant at age IV and females predominated at ages IV and V (Sholar 1977b). In 1979, age classes ranged from II to V; females were predominantly ages IV and V while males were predominantly age III (Fischer 1980).

SANTEE RIVER - In 1974, age V comprised 48% of the population and age class III was the youngest group present (21%)(Curtis 1974).

ST. JOHNS RIVER - Age class III was the dominant age group for both male (63%) and female (68%); ages ranged from II to VI (Williams et al. 1975). Males averaged 3.26 years and females averaged 3.47 years. Aging the St. Johns River population was difficult because the "freshwater zone" or false annulus marked on the scale as juveniles leave freshwater in the spring was indistinguishable from the several false annuli typical for shad in the river system (Williams et al. 1975).

3.7.9.3 Size Composition

Female hickory shad are larger than males of similar age (Table 3.7-4).

3.7.9.4 Abundance and Population Status

Commercial landings of hickory shad in North Carolina were stable for many years but dropped sharply in 1970 and have not recovered. South Carolina has reported commercial landings sporadically since 1964. Georgia landings exhibited peaks in 1968 and 1969, but plunged to former low levels the following year. Hickory shad landings from the Florida east coast have been reported sporadically since 1956. Population

Table 3.7-3. Age composition (%) of hickory shad populations in river systems within Region 4. M = males; F = females; C = sexes combined.

RIVER SYSTEM AND YEAR	SEX	I	II	III	IV	V	VI	VII	VIII	SOURCE(S)
		AGE CLASS								
Neuse River										
1977	M		9	39	31	10	6	4	1	Marshall (1977)
	F		1	33	36	19	6	5	1	
1978	M			9	66	22	3	0		Hawkins (1979)
	F			9	64	20	6	1		
Northeast Cape Fear River										
1976	M			29	65	0	6			Sholar (1977b)
	F				45	55				
1978-79	M			52	33	15				Fischer (1980)
	F			10	40	50				
Santee River										
1974	C			21	31	48				Curtis (1974)
St. Johns River										
1971-74	M		12	62	12	12	2			Williams et al. (1975)
	F		2	73	10	13	2			

Table 3.7-4. Size composition (mean fork length in mm) of hickory shad populations in river systems within Region 4. M = males; F = females; C = sexes combined.

RIVER SYSTEM AND YEAR	SEX	AGE CLASS I	II	III	IV	V	VI	VII	VIII	SOURCE(S)
Albemarle Sound										
1975	M		289	325	350	371	360	365		Street et al. (1975)
	F		341	341	355	387	384	390		
Pamlico Sound and River										
1976	M		286	297	341	355	395	-		Marshall (1976)
	F		290	324	354	376	413	427		
Neuse River										
[illegible]	M		294	332	346	356	357	369		Pate (1972)
	F		311	354	376	395	409	420		
[illegible]	M		294	336	344	356	381	384	397	Marshall (1977)
	F		307	343	357	367	386	415	411	
[illegible]	M			325	343	352	361	-		Hawkins (1979)
	F			338	362	369	403	403		
White Oak River										
[illegible]	M			345	-					Sholar (1975)
	F			-	318					
Northeast Cape Fear River										
1976	M			291	331	-	433			Sholar (1977b)
	F			-	326	349	-			
1978-79	M			300	316	354				Fischer (1980)
	F			308	338	370				
Santee River										
[illegible]	C			411	467	487				Curtis (1974)
St. Johns River										
1971-[illegible]	M	-	[illegible]	340	358	376	384			Williams et al. (1975)
	F	[illegible]	326	352	370	400	420			

estimates of these stocks are lacking for most river systems. The hickory shad population in the Altamaha River was estimated at 117,648 pounds in 1968 (Godwin 1968).

The status of hickory shad in Southeast river systems was estimated from responses to the questionnaire by State and Federal agencies (Section 4). Responses indicate lack of information on hickory shad stocks; status of many stocks was not known (Table 3.7-5). Factors possibly important in contributing to the decline of certain populations are presented in Table 3.7-6.

NORTH CAROLINA - The Neuse and Tar-Pamlico Rivers produce the largest landings of hickory shad in North Carolina (Marshall 1977). The contribution of the Neuse River landings to the hickory shad fishery has varied from 11 to 65% during the period 1918 to 1977; the commercial catch over the last 10 years averaged 28% of the total State hickory shad landings (Hawkins 1979).

FLORIDA - Walburg (1960) reported the "shad" catch in the St. Johns River by sportfishermen was comprised of 2.4% hickory shad. In 1972, American shad outnumbered hickory shad in haul seine samples by a factor of seven (Williams et al. 1975).

3.7.9.5 Factors Affecting Reproduction and Recruitment

Recruitment to the spawning hickory shad population is generally comprised of age III males and ages IV and V females. The total lack of data on juvenile abundance and survival precludes estimation of recruitment.

Repeat spawning is an important life history aspect of hickory shad in Southeast waters. Repeat spawning is very high (over 70%) for Neuse River hickory shad (Pate 1972, Marshall 1977, Hawkins 1979), which suggests that they survive the stress of spawning very well. Hawkins (1979) found up to four spawning marks on females, and Marshall (1977) reported as many as five marks on both sexes. The percentage of repeat spawners is also high in the Pamlico River and Albemarle Sound; only 50% of the males and 48% of the females were virgin during years 1972 through 1974 (Street et al. 1975).

Table 3.7-5. Status of Hickory shad, *Alosa mediocris*, in river systems within Region 4 based on questionnaire responses to question VI-2. S = response from marine representative; F = response from freshwater representative.

RIVER SYSTEM	STATUS
NORTH CAROLINA	
Currituck Sound	
Albemarle Sound	Declining (F)
North R.	
Pasquotank R.	
Little R.	
Perquimans R.	
Yeopim R.	
Chowan R.	Stable (S) or declining (SF)
Meherrin R.	Stable or declining (S)
Roanoke R.	Stable (S) or declining (SF)
Cashie R.	Stable or declining (S)
Scuppernong R.	
Alligator R.	
Pungo R.	
Pamlico R.	
Tar R.	Stable (S) or declining (SF)
Neuse R.	Stable (S) or declining (SF)
Trent R.	Stable or declining (S)
North R.	
Newport R.	
White Oak R.	
New R.	Threatened (S)
Cape Fear R.	Stable (S) or declining (SF)
Northeast Cape Fear R.	Declining (F)
Black R.	
Pee Dee R.	Declining (F)
SOUTH CAROLINA	
Waccamaw R.	Not known (S), Stable (F)
Little Pee Dee R.	Stable (F)
Great Pee Dee R.	Not known (S), Stable (F)
Black R.	Not known (S), Stable (F)
Santee R.	Not known (S), Stable (F)
Cooper R.	Not known (S), Stable (F)
Ashley R.	Not known (S), Stable (F)
Edisto R.	Not known (S), Stable (F)
Ashepoo R.	Not known (S), Stable (F)
Combahee R.	Not known (S), Stable (F)
Sampit R.	Not known [illegible], Stable (F)
Salkehatchie R.	Stable (F)
Lynches R.	[illegible] (S)
Savannah R.	Not known [illegible] (F)

Table 3.7-5. Hickory shad (cont'd.).

RIVER SYSTEM	STATUS
GEORGIA	
Savannah R.	Not known (SF)
Ogeechee R.	Not known (SF)
Altamaha R.	Not known (SF)
Oconee R.	Not known (F)
Satilla R.	Not known (SF)
Ocmulgee R.	Not known (F)
St. Marys R.	Not known (SF)
FLORIDA (Atlantic coast)	
St. Marys R.	Not known (SF)
Nassau R.	Not known (SF)
St. Johns R.	Declining (S), Not known (F)
Pellicer Cr.	Not known (S)
Moultrie Cr.	Probably never present (S)
Tomoka R.	Declining (S)

Table 3.7-6. Factors possibly important or very important in contributing to the decline of certain populations of hickory shad, *Alosa mediocris*, within Region 4 based on questionnaire responses to question I. S = response from marine representative; F = response from freshwater representative; C = response from other agencies.

NORTH CAROLINA

- Channelization (FC)
- Dredge and fill projects (F)
- Dams and impoundments (FC)
- Industrial water intakes (FC)
- Location of industrial discharges (FC)
- Chemical pollution (F)
- Turbidity (F)
- Low oxygen levels (F)
- Sewerage outfalls (C)
- Inadequate fishway facilities (F)
- Inadequate control of water release from dams (C)
- Reduction in spawning habitat (F)
- Reduction in nursery areas (F)
- Poor food availability (F)
- Spawning areas too accessible to fishermen (C)
- Poor water quality (FC)

SOUTH CAROLINA

- Dams and impoundments (S)
- Inadequate fishway facilities (S)
- Reduction in spawning habitat (S)
- Poor water quality (S)

GEORGIA

- Channelization (S)
- Dredge and fill projects (S)
- Dams and impoundments (S)
- Location of industrial discharges (S)
- Chemical pollution (S)
- Thermal effluents (S)
- Reduction in spawning habitat (S)
- Reduction in nursery areas (S)
- Poor food availability (S)
- Spawning areas too accessible to fishermen (S)
- Poor water quality (S)

FLORIDA

- Channelization (S)
- Industrial water intakes (S)
- Low oxygen levels (S)
- Sewerage outfalls (S)
- Reduced freshwater input to estuaries (S)
- Reduction in spawning habitat (S)
- Reduction in nursery areas (S)
- Poor food availability (S)
- Spawning areas too accessible to fishermen (S)
- Poor water quality (S)
- Non-point source pollutants (S)

Northeast Cape Fear River stocks exhibit very low repeat spawning; in 1976 only 29% of males and nine percent of females showed evidence of prior spawning, and only one male had spawned more than once (Sholar 1977b). In 1978-79, 85% of Northeast Cape Fear River individuals were virgin (Fischer 1980). Altamaha River hickory shad have a high number of repeat spawners; only 31% of males and 12% of females were virgin (Street and Adams 1969). In the St. Johns River, both sexes of hickory shad exhibited evidence of multiple spawning, with some having up to five spawning marks (Williams et al. 1975).

3.7.9.6 Mortality

Mortality estimates for hickory shad in Albemarle Sound, North Carolina, were 82% in 1977 (Loesch et al. 1977) and 47% in 1978 (Johnson et al. 1978).

3.7.10 Predator-Prey Relationships

No information available.

3.7.11 Diseases

Linton (1901) reported that the following organisms are parasites of hickory shad: nematodes, *Ascaris* sp.; larval cestodes, *Scolex polymorphus*; and trematodes, *Distomum appendiculatum*. Williams et al. (1975) found a digenetic trematode parasite of the family Hemiuridae in stomachs of adult hickory shad in the St. Johns River.

3.7.12 Exploitation

3.7.12.1 Gear

NORTH CAROLINA - Commercial gear utilized to capture hickory shad include hook-and-line, seines, drift nets, dip nets, and fish wheels (Baker 1968, Hawkins 1979). Over 50% of all hickory shad taken with special devices in North Carolina are taken by dip net (Baker 1968). Drift gill nets employ 82.5 by 101.6 mm stretch mesh (Hawkins 1979). Fish wheels have been operated on Contentnea Creek for hickory shad and river herrings (Hawkins 1979). Neuse River sportfishermen cast or troll with spoons and darts in the still tributaries and flooded swamps away from the main river channel (Hawkins 1979).

SOUTH CAROLINA - Hickory shad are taken every year incidental to American shad. Most gill nets used in the American shad fishery have mesh sizes too large to capture many of the smaller hickory shad; however, they are caught in greater numbers in areas where regulations permit the use of smaller mesh nets (Table 3.6-11). Hickory shad are also taken by rod and reel on the same lures used for American shad (Ulrich et al. 1979).

GEORGIA - Gear used to exploit hickory shad populations are similar to those used in South Carolina. There is no commercial or sport fishery specifically for hickory shad in Georgia (Table 3.6-12).

FLORIDA - No information available.

3.7.12.2 Fishing Areas

NORTH CAROLINA - Areas are probably similar to those fished for American shad.

SOUTH CAROLINA - Little or no information on fishing areas for hickory shad was available; Ulrich et al. (1979) believe areas are similar to those for American shad (Table 3.6-11).

GEORGIA - No information on locations of hickory shad fisheries was available; Ulrich et al. (1979) believe areas are similar to those for American shad (Table 3.6-12).

FLORIDA - No information available.

3.7.12.3 Fishing Seasons

Drift gill netting activity in the Neuse River begins in late February or early March, and rod and reel are used by sport fishermen during the spring spawning run (Hawkins 1979).

SOUTH CAROLINA - The season for hickory shad is the same as for American shad (Table 3.6-11). In 1978, shad season occurred from 15 January to 15 April in the Savannah River; seasons for other areas are set according to river systems and river mile.

GEORGIA - The season for hickory shad is the same as for American shad (Ulrich et al. 1979). Season is set by the Board of Natural Resources between 1 January and 31 April of each year, and the season is closed from 1 May through 31 December of each year (Table 3.6-12).

FLORIDA - No information available.

3.7.12.4 Effort

NORTH CAROLINA - Commercial landings of hickory shad in North Carolina exhibited a recent peak in 1945, when 854,000 pounds (Table 3.7-7), representing 0.48% of total finfish landed (Table 3.7-8), brought $68,000 (Table 3.7-9), representing 1.82% of the total finfish dockside value (Table 3.7-10). Commercial landings declined in 1970 and have not recovered.

The recreational fishery for hickory shad is most important in the Neuse, Cape Fear, and Roanoke Rivers. During the period 1 April 1967 to 31 March 1968, hickory shad comprised 20% of the sport catch in these three rivers (Baker 1968). During the same period, the Neuse River sustained more fishing pressure via special devices (bow nets, dip nets, and seines) than any other coastal river (Baker 1968). The Neuse River recreational catch far exceeds the commercial catch, and more hickory shad are taken through the sportfishery (60% by hook-and-line) than all other streams combined (Baker 1968). The harvest of hickory shad in the Northeast Cape Fear River is not great; some are caught in herring nets, but most are harvested by haul seines (Sholar 1977b). Most fishermen believe hickory shad are river herring and treat them as such, probably resulting in low reported landings from the Cape Fear River system (Sholar 1977b).

SOUTH CAROLINA - Commercial landings of hickory shad from South Carolina waters have been reported sporadically since 1964 (Table 3.7-7). These landings typically brought little more than $1,000 each year (Table 3.7-9), which represented less than one percent of total finfish value (Table 3.7-10). Most of the effort by commercial fishermen is directed toward the American shad, and hickory shad catches are incidental.

There is no sportfishery specifically for hickory shad in South Carolina (Ulrich et al. 1979).

GEORGIA - Commercial landings for hickory shad in Georgia have been consistently low for many years. A recent peak in landings occurred in 1968 and 1969 (Table 3.7-7). These catches represented over 1.25% of total finfish landed in the State in both years (Table 3.7-8) but comprised less than one percent of total finfish value (Table 3.7-10).

The increased hickory shad catch in the Altamaha River from 1967 to 1968 was directly attributable to the use of smaller mesh gill nets, increasing the 1968 catch to almost 20 times that of 1967 (Godwin 1968). The escapement rate was estimated for 70.2% for females and 87.1% for males, for an overall 76.1% rate of escapement from the 1968 fishery (Godwin 1968). The increase in effort for 1968 (only 10%) was not proportional to the increase in landings indicating the greatly increased catch was due to a large increase in the shad run for 1968 (Godwin 1968).

FLORIDA - Commercial catches of hickory shad are incidental to those directed toward the American shad fishery. Only 2.4% of the "shad" catch in the St. Johns River are hickory shad, and since they are often mistaken for American shad, data for reported landings are poor. Commercial landing statistics have been reported sporadically since 1956 (Table 3.7-7).

3.7.13 Protection and Management

3.7.13.1 North Carolina

Marshall (1977) reviewed the status of hickory shad in North Carolina and made recommendations for preservation of the resource. Trends in hickory shad abundance have tended to follow those for American shad; however, the latest dramatic decline has been much greater than that for American shad. Although commercial effort has dropped, the older males and females are taken by shad fishermen, which may contribute to population decline. Dams may limit spawning areas, particularly in the Neuse and Tar Rivers - the centers of hickory shad abundance in North Carolina (Marshall 1977).

Commercial catch-effort information is needed and [illegible] Catch-effort statistics for the recreational fishery have provided much needed information but more data should be collected. The location and extent of nursery

areas should be defined to ensure their protection. Indices of juvenile relative abundance should be developed for estimation of recruitment and mortality (Marshall 1977). Restrictions on the fishery to allow stocks to rebuild was also suggested by Marshall (1977), but he warned that actions taken to improve hickory shad stocks should be coordinated with efforts on the more economically-important American shad because of their similarity in harvest and utilization.

3.7.13.2 South Carolina

Populations of juvenile hickory shad in the Pee Dee and Waccamaw Rivers are relatively small, indicating the need for protecting spawning adults in order to improve recruitment (Crochet et al. 1976). The navigation lock at Pinopolis Dam is the only access that hickory shad have to the upper Santee-Cooper watershed (Crochet et al. 1976).

3.7.13.3 Georgia

Godwin (1968) suggested management activities needed to protect the hickory shad resource in Georgia. Commercial fishing seasons lasting into April have resulted in the harvest of spawning fish that were in poor market condition and brought low prices to fishermen. Earlier closing of the commercial fishing season may alleviate this condition. By using experimental gill nets of varying mesh size, the 1967-68 catch revealed that use of smaller mesh nets (four inches) would decrease the percentage of female American shad taken and increase the percentage of male American shad and hickory shad taken. This change in mesh size was proposed by Godwin (1968) as a means to conserve the American shad resource, but will increase exploitation of hickory shad.

3.7.13.4 Florida

Williams et al. (1975) concluded that management of the hickory shad population in the St. Johns River was not practical for the present.

Table 3.7-7. Hickory shad landed (thousands of pounds).

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA	TOTAL
1939	253	7	5	43	.	.	.	.	308
1940	336	18	13	5	.	.	.	.	372
1945	854	12	18	86	.	.	.	.	970
1950	295	20	7	15	.	.	.	.	337
1951	196	11	6	60	.	.	.	.	273
1952	453	10	9	.	.	.	.	.	472
1953	439	8	6	6	.	.	.	.	459
1954	324	.	1	7	.	.	.	.	331
1955	251	.	5	16	.	.	.	.	[illegible]
1956	268	23	.	31	.	.	.	.	322
1957	248	6	3	.	.	.	.	.	257
1958	84	1	1	34	.	.	.	.	120
1959	99	1	5	.	.	.	.	.	105
1960	181	3	4	.	.	.	.	.	188
1961	276	1	3	.	.	.	.	.	280
1962	172	1	2	.	.	.	.	.	175
1963	292	1	.	.	.	.	.	.	293
1964	233	2	1	.	.	.	.	.	236
1965	202	.	1	.	.	.	.	.	203
1966	197	.	2	1	.	.	.	.	200
1967	130	.	1	.	.	.	.	.	131
1968	141	.	11	.	.	.	.	.	152
1969	101	2	12	.	.	.	.	.	115
1970	61	3	.	.	.	.	.	.	[illegible]
1971	63	.	2	.	.	.	.	.	65
1972	69	3	2	.	.	.	.	.	74
1973	66	.	4	.	.	.	.	.	70
1974	42	.	1	.	.	.	.	.	[illegible]
1975	29	2	1	.	.	.	.	.	32
1976	19	.	.	.	.	.	.	.	[illegible]
1977	22	.	.	.	.	.	.	.	.
1978	21	.	.	.	.	.	.	.	.
1979	32	.	.	.	.	.	.	.	.
1980	92	.	.	.	.	.	.	.	.

Table 3.7-8. Pounds landed (%) of hickory shad in the total commercial catch of finfish by state.

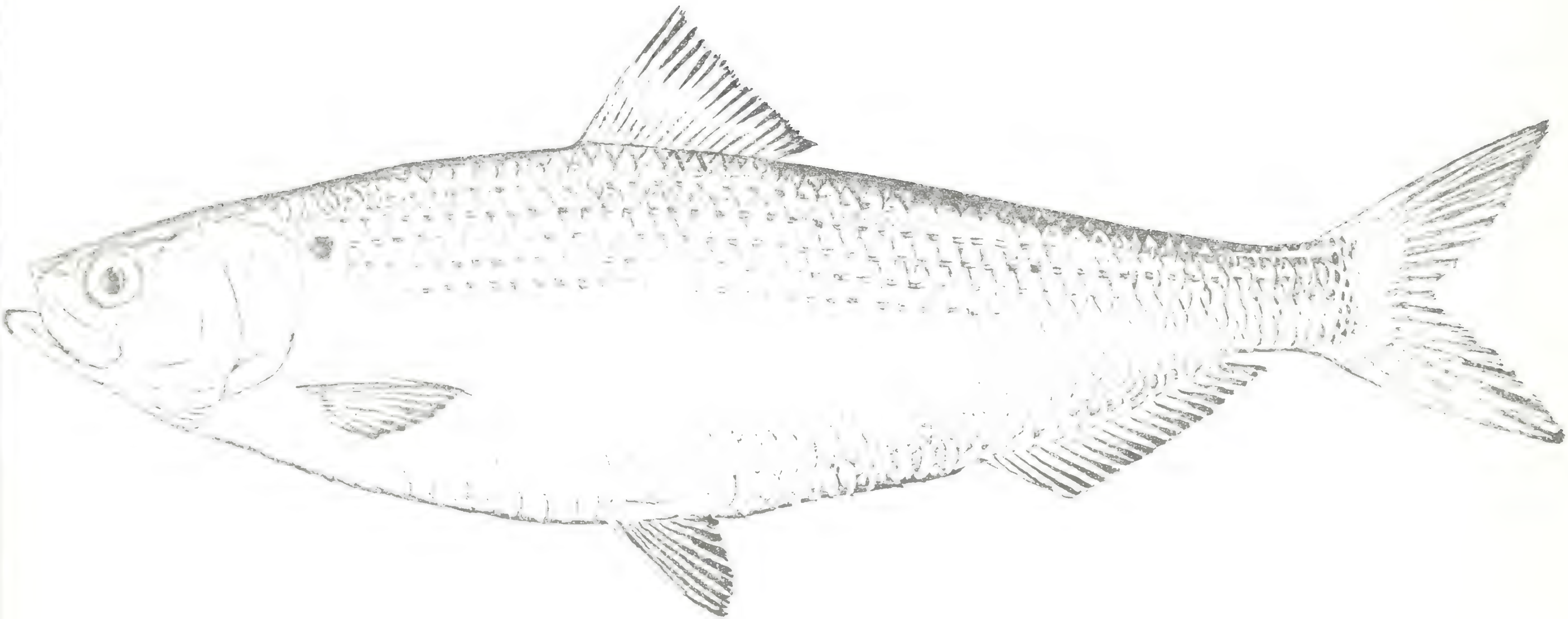
YEAR	NC	SC	CA	FL(E)	FL(W)	AL	MS	LA
1939	0.12	0.55	[illegible]	0.02	.	.	.	.
1940	0.21	1.37	1.80	0.00	.	.	.	.
1945	0.48	0.40	[illegible]	0.04	.	.	.	.
1950	0.19	0.74	[illegible]	0.03	.	.	.	.
1951	0.14	0.11	[illegible]	[illegible]	.	.	.	.
1952	0.20	[illegible]	[illegible]	.	.	.	.	.
1953	0.27	[illegible]	[illegible]	0.01	.	.	.	.
1954	0.17	.	.	0.01	.	.	.	.
1955	0.12	.	[illegible]	0.03	.	.	.	.
1956	0.09	0.27	[illegible]	[illegible]	.	.	.	.
1957	0.11	[illegible]	[illegible]	.	.	.	.	.
1958	[illegible]	[illegible]	[illegible]	0.09	.	.	.	.
1959	0.03	0.01	0.47	.	.	.	.	.
1960	0.07	[illegible]	[illegible]	.	.	.	.	.
1961	0.10	0.01	[illegible]	.	.	.	.	.
1962	0.11	0.01	[illegible]	.	.	.	.	.
1963	0.13	0.01	[illegible]	.	.	.	.	.
1964	0.11	[illegible]	[illegible]	.	.	.	.	.
1965	0.10	.	[illegible]	.	.	.	.	.
1966	0.09	.	[illegible]	0.00	.	.	.	.
1967	[illegible]	.	[illegible]	.	.	.	.	.
1968	0.07	.	[illegible]	.	.	.	.	.
1969	[illegible]	[illegible]	[illegible]	.	.	.	.	.
1970	0.14	[illegible]	[illegible]	.	.	.	.	.
1971	0.05	.	[illegible]	.	.	.	.	.
1972	[illegible]	[illegible]	0.19	.	.	.	.	.
1973	0.06	.	[illegible]	.	.	.	.	.
1974	[illegible]	.	[illegible]	.	.	.	.	.
1975	0.01	[illegible]	[illegible]	.	.	.	.	.
1976	0.01	.	.	.	.	.	.	.
1977	0.01	.	.	.	.	.	.	.
1978	0.01	.	.	.	.	.	.	.
1979	0.01	.	.	.	.	.	.	.
1980	0.00	.	.	.	.	.	.	.

Table 3.7-9. Dockside value of hickory shad (thousands of dollars).

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA	TOTAL
1939	7	0	0	1	.	.	.	.	8
1940	12	0	1	0	.	.	.	.	13
1945	68	2	1	4	.	.	.	.	75
1950	14	2	1	1	.	.	.	.	18
1951	14	2	1	2	.	.	.	.	19
1952	20	2	1	.	.	.	.	.	23
1953	17	1	1	1	.	.	.	.	20
1954	17	.	.	1	.	.	.	.	18
1955	12	.	1	1	.	.	.	.	14
1956	16	2	1	1	.	.	.	.	20
1957	15	1	1	.	.	.	.	.	17
1958	5	1	1	1	.	.	.	.	8
1959	6	1	1	.	.	.	.	.	9
1960	9	1	1	.	.	.	.	.	10
1961	14	1	1	.	.	.	.	.	15
1962	9	1	1	.	.	.	.	.	10
1963	9	1	1	.	.	.	.	.	10
1964	9	1	1	.	.	.	.	.	10
1965	7	.	1	.	.	.	.	.	8
1966	6	.	1	1	.	.	.	.	7
1967	8	.	1	.	.	.	.	.	9
1968	6	.	1	.	.	.	.	.	7
1969	5	1	2	.	.	.	.	.	[illegible]
1970	3	1	1	.	.	.	.	.	5
1971	3	.	1	.	.	.	.	.	4
1972	4	1	1	.	.	.	.	.	6
1973	3	.	1	.	.	.	.	.	[illegible]
1974	3	.	1	.	.	.	.	.	[illegible]
1975	2	1	1	.	.	.	.	.	[illegible]
1976	2	.	.	.	.	.	.	.	[illegible]
1977	2	.	.	.	.	.	.	.	[illegible]
1978	4	.	.	.	.	.	.	.	[illegible]
1979	5	.	.	.	.	.	.	.	[illegible]
1980	13	.	.	.	.	.	.	.	[illegible]

Table 3.7-10. Dockside value (%) of hickory shad in the total commercial catch of finfish by state.

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA
1939	0.46	0.38	0.53	0.06	.	.	.	.
1940	0.79	0.71	1.14	0.00	.	.	.	.
1945	1.82	0.4[illegible]	0.77	0.03	.	.	.	.
1950	0.37	0.94	0.76	0.02	.	.	.	.
1951	0.44	0.30	0.40	0.05	.	.	.	.
1952	0.48	0.64	0.66	.	.	.	.	.
1953	0.48	0.57	[illegible]	0.03	.	.	.	.
1954	0.40	.	.	0.07	.	.	.	.
1955	0.30	.	0.78	0.03	.	.	.	.
1956	0.30	0.38	[illegible]	0.03	.	.	.	.
1957	0.33	0.20	0.75	.	.	.	.	.
1958	0.29	0.33	0.74	0.03	.	.	.	.
1959	0.12	0.27	0.61	.	.	.	.	.
1960	0.23	0.13	0.21	.	.	.	.	.
1961	0.32	0.07	0.33	.	.	.	.	.
1962	0.27	0.08	0.24	.	.	.	.	.
1963	0.21	0.03	0.33	.	.	.	.	.
1964	0.20	0.07	0.37	.	.	.	.	.
1965	0.14	.	0.24	.	.	.	.	.
1966	0.12	.	0.32	0.01	.	.	.	.
1967	0.17	.	0.34	.	.	.	.	.
1968	0.13	.	0.53	.	.	.	.	.
1969	0.10	0.04	0.85	.	.	.	.	.
1970	0.07	0.76	0.45	.	.	.	.	.
1971	0.07	.	0.14	.	.	.	.	.
1972	0.07	0.14	0.34	.	.	.	.	.
1973	0.03	.	0.41	.	.	.	.	.
1974	0.03	.	0.20	.	.	.	.	.
1975	0.02	0.16	0.36	.	.	.	.	.
1976	0.01	.	.	.	.	.	.	.
1977	0.01	.	.	.	.	.	.	.
1978	0.02	.	.	.	.	.	.	.
1979	0.03	.	.	.	.	.	.	.
1980	0.04	.	.	.	.	.	.	.



Blueback herring

Alosa aestivalis

3.8 Blueback Herring (*Alosa aestivalis*)

3.8.1 Historical Significance

Blueback herring - also known as glut herring, blackbelly, sawbelly, summer herring, and blueback - reaches its northern limit in Canada and occurs along the eastern North American coast southward from Cape Breton, Nova Scotia, to northern Florida (Scott and Crossman 1973). Blueback and alewife (*Alosa pseudoharengus*) are marketed together as "river herring" and are caught commercially in every Atlantic coast State except Georgia (Street 1970). Both species are sold fresh or salted for human consumption, but most are utilized as crab bait and fish meal (Pate 1974).

3.8.1.1 North Carolina

The history of the river herring fishery in North Carolina was summarized by McCoy (1976). North Carolina's river herring fishery is historically important and began prior to the American Revolution. Salted river herring was an important item for export from North Carolina's colonial ports. Huge seines up to two miles in length were the chief fishing gear until the post-Civil War period. Pound nets were introduced at that time and presently produce about 95% of the total catch (McCoy 1976).

Peak pound net catches generally occur during the last half of April, coinciding with the spawning peak of bluebacks. During this period, the catch is composed largely of spent fish emigrating from the upstream spawning areas. The inshore fishery is not dependent on any single year class but is entirely dependent on sexually-mature fish. The offshore fishery depends mostly on sexually-immature fish (McCoy 1976).

Mortality data indicate that the total blueback population in North Carolina has declined drastically in recent years, and the cause has been by some process that harvests all age groups from the population. Mortality increased sharply in 1975. The general decline appears to have been caused by the offshore trawl fishery, much of which is operated by foreign countries. Current restriction placed on the trawl fishery was inadequate to permit recovery of blueback stocks. The trawl fishery has been in existence since 1967 (McCoy 1967).

At the turn of the century, the Cape Fear River system was one of the most productive North Carolina streams for clupeids. Blueback ascended the Cape Fear

River to Smiley Falls near Lillington and spawned from the mouth of the Black River to Fayetteville, a distance of 100 miles (Davis and Cheek 1966). From 1913 to 1934, three navigational locks were constructed on the Cape Fear River. The dams were provided with ladder-type fishways, but anadromous fishes did not use them. In 1962, a joint effort was initiated by the North Carolina Wildlife Resources Commission, Fish and Wildlife Service, and the Corps of Engineers to determine the feasibility of passing anadromous fish through these locks and allowing them to migrate upstream to historical spawning grounds. This locking procedure has resulted in restoring a portion of these runs in recent years (Davis and Cheek 1966). Fishermen on the Cape Fear River once caught truckloads of herring in seines, but in 1976 only 34 to 45 kg of herring were caught per day during the peak of the spawning run (Sholar 1977b).

3.8.1.2 South Carolina

Blueback herring is the most abundant anadromous species in South Carolina and plays an important role in the aquatic ecology of the Santee-Cooper system (Bulak and Curtis 1978). Every year since 1975, an average of 3.5 million herring are passed into the upper Santee-Cooper system through the Pinopolis Navigation Lock. The locks are operated three times a day, seven days a week for fish passage. The yearly influx of bluebacks helps to maintain the nationally-famous striped bass fishery in Lakes Marion and Moultrie. Bluebacks also support both a commercial and live bait fishery within the reservoirs and rivers of the Santee-Cooper system (Bulak and Curtis 1978).

A significant dip net fishery for blueback herring has been conducted in Cooper River for a number of years. This fishery has declined drastically since 1969. During 1974 and 1975, restrictions were placed on the river fishery to insure that major fishing pressure was delayed until after the primary spawning period. However, these efforts may have been fruitless; tagged bluebacks were recaptured by an East German trawler off Cape Cod in 1971 (McCoy 1976).

3.8.1.3 Georgia

Blueback herring are near their southern range limit in the Altamaha River, Georgia (Hildebrand 1963). Although they are the most abundant species in the Altamaha, the population remains relatively unexploited due to restriction of commercial fishery gear types (Street 1970). A few

bluebacks are taken by American shad fishermen. The large blueback population suggests the potential for a commercial fishery (Street 1970).

3.8.1.4 Florida

The blueback herring is Florida's smallest anadromous clupeid species. Bluebacks caught in Florida waters were once salted and shipped to Northern and Midwestern markets, but they have declined in importance since widespread refrigeration made other fish species available. In the St. Johns River, blueback are used presently as bait for catfish and crab industries (Williams et al. 1975).

3.8.2 Distribution

3.8.2.1 Range

Blueback range from Cape Breton, Nova Scotia, (Scott and Crossman 1973) to northern Florida (Hildebrand 1963). Bluebacks are well-established in the St. Johns and St. Marys Rivers in Florida, with minor populations in the Nassau and Tomoka Rivers (Williams and Grey 1975).

3.8.2.2 Eggs

Blueback eggs are essentially pelagic, but are demersal in still water and somewhat adhesive (Lippson and Moran 1974).

3.8.2.3 Larvae

Larvae are found throughout river systems, with primary abundance in creeks and tributaries.

3.8.2.4 Juveniles

Juvenile blueback are dispersed throughout river systems but congregate in creeks and tributaries during summer months, then migrate to overwintering areas during fall. These areas may be sounds, bays, or deeper portions of estuaries (Hildebrand and Schroeder 1928, Street et al. 1975, Marshall 1977).

3.8.2.5 Adults

Blueback herring is an anadromous, schooling species which inhabits a narrow band of coastal water and enters fresh or brackish water to spawn in spring (Jones et al. 1978). Location of the parental stock

is not well-defined; they apparently move offshore to bottom waters during winter (Hildebrand 1963).

3.8.3 Reproduction

3.8.3.1 Maturity

Minimum age to maturity appears to be three years (Loesch 1969). Size at maturity is 250 mm or less (Hildebrand 1963); no female blueback less than 230 mm FL was sexually mature in offshore North Carolina waters (Johnson et al. 1978).

3.8.3.2 Mating

No information available.

3.8.3.3 Fertilization

Eggs are released in grasses or vegetation and are fertilized (Frankensteen 1976).

3.8.3.4 Fecundity

Egg production and retention increases with fish length up to 300 mm but then declines in larger females (Loesch 1969, Loesch and Lund 1977). Street (1970) estimated Altamaha River blueback contained 120,000 to 400,000 eggs, with a mean of 244,000. Bluebacks in the St. Johns River contained between 151,000 to 349,000 eggs per female, with a mean of 262,000; fecundity was correlated better with weight than with length or age (Williams et al. 1975).

3.8.4 Spawning

3.8.4.1 Season and Location

Blueback spawning is initiated later in the season with increased latitude. Spawning begins in January in the St. Johns River (Table 3.8-1) and continues into mid-July in northern latitudes. Spawning locations (Table 3.8-2) vary among river systems but occur mainly in tributary creeks in shallows over vegetation.

3.8.4.2 Temperature

Spawning activity of blueback has been recorded at temperatures as low as 13 C (Hawkins 1979) and ceases at temperatures greater than 27 C. Spawning temperatures in specific river systems are:

NEUSE RIVER - 13 to 26 C (Hawkins 1979).
NORTHEAST CAPE FEAR RIVER - peak 17 C (Sholar 1977b).
SANTEE RIVER - peak 17 C (Bulak and Curtis 1978).
COOPER RIVER - peak 19 C (Bulak and Curtis 1978).
ALTAMAHA RIVER - 15 to 20 C (Street 1970).
ST. JOHNS RIVER - 15.5 to 17 C (Williams et al. 1975).

3.8.4.3 Spawning Habitat

Blueback herring in Southeast waters have been reported spawning over shallow areas covered with vegetation (Frankensteen 1976), ricefields (Christie 1978), and upstream river swamp areas and smaller tributaries above the tidal zone (Godwin and Adams 1969, Street 1970).

3.8.4.4 Diel Spawning Patterns

Movement to spawning grounds in the Connecticut River occurs in late afternoon or at night (Loesch 1969).

3.8.5 Life History - Eggs and Larvae

3.8.5.1 Hatching and Growth

The incubation period for fertilized blueback eggs ranges from 80 to 94 hours at 20-21 C (Morgan and Prince 1976), 36 to 38 hours at 22 C (Street and Adams 1969), 50 hours at 22 C (Bigelow and Schroeder 1953), and 55 to 58 hours at 22.2 to 23.7 C (Cianci 1969).

GROWTH - Length at hatching ranges from 3.1 to 5.0 mm TL, averaging 4.3 mm TL. Duration of the yolk-sac stage is two to three days and average length is 5.1 mm TL (Jones et al. 1978). Larvae become juveniles at approximately 20 mm TL.

FEEDING - No information available.

METABOLISM - No information available.

3.8.5.2 Hardiness

There was no information available on the hardiness of blueback eggs and larvae to the following environmental variables: salinity, salinity-temperature interaction, acclimation, oxygen, pH, and transport.

Table 3.8-1. Spawning season of blueback herring.

RIVER SYSTEM	SEASON	SOURCE(S)
Neuse River	Late March to late May	Hawkins (1979)
White Oak River	Early April to mid-May; peak late April	Sholar (1975)
Northeast Cape Fear River	March through May	Sholar (1977b)
Cape Fear River	Mid-March to early May; peak in April	Fischer (1980)
Santee-Cooper system	Santee blueback spawn earlier and with shorter duration compared to Cooper blueback	Bulak and Curtis (1978)
St. Johns River	January to early May; peak in February or March	Williams et al. (1975)
Altamaha River	Late March to mid-April	Street (1970)

Table 3.8-2. Spawning grounds of blueback herring.

RIVER SYSTEM	LOCATION	SOURCE(S)
Alligator River	Alligator River Northwest fork; Frying Pan; Cherry Ridge Landing; Gum Neck Landing (pumping station); East Lake (lower); South Lake (upper); Second Creek	Loesch et al. (1977)
Roanoke River	Gardners Creek (SR 1511); Conoho Creek mouth; Conine Creek mouth; Cow Creek	Johnson et al. (1978)
Cashie River	SR 1225; SR 1514	Johnson et al. (1978)
Neuse River	SR 1008 bridge downstream to New Bern	Hawkins (1979)
Swift Creek	SR 1440 bridge to mouth	
Little Swift Creek	SR 1627 bridge to mouth	
Batchelor Creek	US 70 bridge to mouth	
Pinetree Creek	Entire creek	
Turkey Quarter	Entire creek	
Taylor Creek	Entire creek	
Pitchkettle Creek	Entire creek	
Halfmoon Creek	Entire creek	
Kitten Creek	Entire creek	
Village Creek	Entire creek	
Contentnea Creek	NC Hwy 13 bridge (Snow Hill) to mouth	
Little River	NC Hwy 581 bridge to mouth	
Trent River	Pleasant Hill to SR 1121	Marshall (1977)
White Oak River	Primary area: Quarry Lakes; Holston Creek, Grant Creek	Sholar (1975)
Northeast Cape Fear River	Croom's Bridge downstream to Long Creek	Sholar (1977b)
Cape Fear River	Lilliput Creek (10 miles below Wilmington) to Brown's Creek (RM 70) and other creeks and sloughs off main river	Fischer (1980)
Cooper River	Primary areas: Tailrace canal and Berkeley Country Club; also Pimlico, West Branch, East Branch, and extensive ricefields	Bulak and Curtis (1978)

Table 3.8-2. Spawning grounds (cont'd.).

RIVER SYSTEM	LOCATION	SOURCE(S)
Santee River	Primary area: River Km 60 near Jamestown	Bulak and Curtis (1978)
St. Johns River	Primary area: south of Lake George extending 176 km south to the area immediately south of Lake Poinsett; also Black Creek, Dunn's Creek, Six Mile Creek, and Econlockhatchee River	Williams et al. (1975)
Altamaha River	Upstream river swamp areas and smaller tributaries above the tidal zone (RM 100 to 120)	Godwin and Adams (1969) Street (1970)

TEMPERATURE - Blueback herring eggs subjected to simulated power plant effects (7 to 20 C above ambient) indicated that absolute hatching success was 10 to 14% below that for control eggs; no behavioral or morphological differences were observed (Schubel and Auld 1973). Time-excess temperatures of six to 10 C and 2.5 to 60 minutes (cooling time 60 to 300 minutes) did not significantly alter hatching success (Schubel 1974). Larvae developing from eggs stressed by prolonged temperatures, similar to those encountered during entrainment through power plants, were deformed. Larvae exhibited shortened bodies, enlarged finfolds, and curved or twisted spines; the severity and incidence was related to the elevated temperature and the exposure time (Koo and Johnston 1978). The lack of normal swimming ability suggested poor eventual survivability (Koo and Johnston 1978).

SUSPENDED SEDIMENTS - Concentrations of suspended sediments less than 100 mg l^{-1} had no significant effect on the hatching success of blueback eggs (Auld and Schubel 1978).

3.8.5.3 Swimming Ability

Prolarvae are postively phototrophic (Mansueti 1956) and swim in spasms toward the surface. They then sink to the bottom where they lie for several seconds, then begin to swim again to the surface (Cianci 1969).

3.8.5.4 Chemical Tolerances

CHLORINE - Blueback herring eggs subjected to residual chlorine exhibited LC_{50} values at concentrations of 0.20 to 0.40 ppm. Age-related effects in chlorine sensitivity were also observed (Morgan and Prince 1977). Larvae exhibited LC_{50} values at concentrations of 0.20 to 0.32 ppm total residual chlorine. Abnormal larvae hatched from blueback eggs exposed to low chlorine concentrations (Morgan and Prince 1977).

3.8.5.5 Pressure

No information available.

3.8.6 Juveniles

3.8.6.1 Nutrition and Growth

FEEDING - McLane (1955) reported that juvenile blueback in the St. Johns River fed on Cladocera and Copepoda. Juveniles in the Cape Fear River principally feed on small planktonic crustaceans and crustacean eggs (Davis and Cheek 1966). Food items were not as varied as those of American shad, indicating that the blueback is a selective feeder. No bottom organisms or gravel were found in stomach contents. Dipteran larvae appeared frequently in guts but did not constitute a major portion of the diet. Juveniles apparently fed to some extent throughout the day (Davis and Cheek 1966). Burbidge (1974) observed a relationship between standing crops of zooplankton and distribution of juvenile bluebacks in the James River, Virginia. Zooplankton densities were highest upstream where juvenile blueback maintained highest growth rate. Prey items consisted primarily of copepods but cladocerans were also ingested. Selection was strongest for adult copepods and weakest for copepod nauplii. Fe ding only occurred during daylight hours (Burbidge 1974).

GROWTH - Juvenile blueback herring in the Cape Fear River grew from 49.3 mm FL in July to a mean of 57.4 mm FL in November 1964; growth in the Northeast Cape Fear and Black Rivers was below this rate (Davis and Cheek 1966). Juveniles in the Altamaha River experience rapid growth rate from July through November. Mean lengths increased from 34.8 mm in July to 60.6 mm in November, a 25.8 mm increase over four months (Godwin and Adams 1969). Average mean lengths and weights of young increased from 32.0 to 57.8 mm FL and 0.51 to 2.12 g over a 19-week period (Godwin 1968). A study by Street (1970) observed six mm larvae in April growing to 65 mm juveniles in November, which was a slower growth rate than that observed for hickory shad in the same river system. Juvenile blueback in Connecticut remain in freshwater longer than alewives; thus, more growth would be expected (Marcy 1969).

METABOLISM - Routine metabolism was calculated for young-of-the-year blueback, represented by the expression

$$\text{Log } 0 = 1.4451 + 0.0548 \text{ T},$$

where 0 is milligrams of oxygen per gram wet weight per hour, and T is temperature expressed in degrees C.

The mean maintenance requirement (percent food assimilated) was 88.3% compared to 11.7% (food assimilated) required for growth (Burbidge 1974).

3.8.6.2 Hardiness

No information was available on the hardiness of juvenile bluebacks to the following fluctuating variables: temperature, salinity-temperature interaction, acclimation, suspended sediments, pH, and transport.

SALINITY - Juvenile blueback 34 to 52 mm TL are highly salinity tolerant early in life and can withstand transfer from brackish water (5 ^{o}/oo) to near seawater (28 ^{o}/oo)(Chittenden 1972a).

OXYGEN - Mass mortalities of blueback herring occurred in the lower 48 km of the Connecticut River during summer (June and July) 1965, 1966, 1967, and 1971. Death occurred in early morning when dissolved oxygen levels fell in ranges below 1.3 mg 1^{-1} at 24.6 C and 3.6 mg 1^{-1} at 27.6 C (Moss et al. 1976).

3.8.6.3 Swimming Ability

No information was available on the swimming ability of juvenile blueback herring.

3.8.6.4 Chemical Tolerances

KEPONE - Juvenile blueback herring captured in nursery areas of the lower Chickahominy River and James River (RM 56 to 69) all contained kepone concentrations above the action level (0.3 ppm). Kepone concentrations per unit body weight may reach a saturation level early in juvenile development, and further increases in juvenile Kepone body burden are proportional to growth (Johnson et al. 1978).

3.8.6.5 Pressure

Information concerning the effects of pressure on juvenile bluebacks was not available.

3.8.7 Life History - Adults

3.8.7.1 Longevity

Little information is available on the average life expectancy of blueback herring. Commercial and recreational fisheries tend to crop the few remaining

old adults from the spawning population, and the lack of elder adults indicates an overfishing problem. The oldest adult blueback (age IX) reported from Southeast waters was from Albemarle Sound (Meherrin River) by Holland et al. (1975).

3.8.7.2 Nutrition and Growth

FEEDING - Adult blueback herring 167 to 241 mm FL were captured 15 February 1971 in offshore North Carolina waters and examined for food items. All stomachs contained zooplankton (amphipods, copepods, isopods, cumaceans, mysids, and decapod larvae). None of the stomachs contained fish or fish remains (Holland and Yelverton 1973).

GROWTH - The length-weight relationships of blueback herring offshore North Carolina and at Tunis, North Carolina, in the Chowan River were calculated by Holland and Yelverton (1973). The following results were obtained:

FORK LENGTH-AGE RELATIONSHIP

Chowan River (1969 to 1971) -

Males $A = 197.90L^{0.10}$, $r = 0.85$

Females $A = 200.90L^{0.12}$, $r = 0.95$

FORK LENGTH-WEIGHT RELATIONSHIP

Chowan River (1969 to 1971) -

Males $W = 9.01 \times 10^{-6} L^{3.08}$, $r = 0.73$

Females $W = 2.15 \times 10^{-5} L^{2.92}$, $r = 0.66$

Offshore North Carolina (1969 to 1971) -

Combined $W = 4.51 \times 10^{-6} L^{3.20}$, $r = 0.98$.

(Holland and Yelverton 1973).

METABOLISM - No information available.

3.8.7.3 Hardiness

Little information was available concerning the hardiness of adult blueback herring to the following variables: salinity, temperature, salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport.

3.8.7.4 Swimming Ability

The swimming ability of adult blueback herring has not been determined.

3.8.7.5 Chemical Tolerances

KEPONE - None of the adult blueback herring collected from lower Chesapeake Bay and tributaries contained Kepone concentrations exceeding the action level (0.3 ppm) in body tissues or roe (Johnson et al. 1978).

3.8.7.6 Pressure

Effects of pressure on adult blueback herring have not been determined.

3.8.8 Behavior

3.8.8.1 Juvenile Migration and Local Movement

NEUSE RIVER - The nursery area for juvenile blueback herring (Table 3.8-3) is characterized by deep, black waters draining hardwood swamps, little salinity or current, and a mud and detritus bottom. No juveniles were captured below the nursery area until after the fall migration in October 1976 (Marshall 1977). Secondary nursery areas are characterized as shallow, high-salinity tributaries. These areas are utilized as overwintering areas from October through March before juveniles migrate to the ocean in the spring. Total migration occurs as the adult spring migration begins (Marshall 1977). Overwintering areas for Neuse River juveniles are located in the lower Neuse and western Pamlico Sound (Spitsbergen and Wolff 1974). Juveniles are found close to shorelines in creeks and the mainstem of the river (Hawkins 1979). Heavy rainfall and flooding contributed to significant downstream transport of juveniles in 1978 (Hawkins 1979).

NEW RIVER - Nursery areas are utlized by juveniles in October and November (Sholar 1975).

WHITE OAK RIVER - Juvenile blueback remained in the freshwater zone of the White Oak from July through November with peak abundance in October. Seaward migration occurred after October (Sholar 1975).

Table 3.8-3. Nursery areas of juvenile blueback herring.

RIVER SYSTEM	LOCATION	SOURCE(S)
Albemarle Sound	Pasquotank River, Little River, Perquimans River, Chowan River, lower Roanoke River, Scuppernong River, Alligator River, and the periphery of Albemarle Sound	Loesch et al. (1977)
Pamlico Sound	Western and northern ends are used as secondary nursery areas October through March	Spitsbergen and Wolff (1974) Marshall (1976)
Croatan Sound	Used as a secondary nursery area October through March	[illegible] et al. (1975)
Tar-Pamlico system	Hardee Creek area to Washington, and Goose, Broad, and Blounts Creeks	Hawkins (1979)
Neuse-Trent system	Primary areas Neuse: mouth of Cove Creek downstream to mouth of Batchelor Creek (21 km); Trent: Pollocksville downstream to mouth [illegible] Island Creek	Marshall (1977)
New River	Lower channelized area only in October and November	Sholar (1975)
White Oak River	Freshwater zone of White Oak Rivers, and Webb, Grant and Hunter Creeks July through November	Sholar (1975)
Northeast Cape Fear River	River mouth to 5 miles north of NC Hwy 53 bridge (44 miles), and Smith, Ness, Long, Turkey, Prince George, Island, Harrison, Merrick, and Lillington Creeks	Davis and Cheek (1966) Sholar (1977b)
Black River	River mouth to [illegible]	Davis and Cheek (1966)

Table 3.8-3. Nursery Areas (cont'd.).

RIVER SYSTEM	LOCATION	SOURCE(S)
Cape Fear River	RM 20 to RM 119 (Lock No. 3); Indian Creek, Brunswick River, Cartwheel Branch, Alligator Creek, Sturgeon Creek, and Mallory Bay	Davis and Cheek (1966) Fischer (1980)
Altamaha River	RM 0 to RM 40 in all river zones	Smith (1968) Godwin and Adams (1969)
	RM 11 to RM 30 in tidal freshwater	Street (1970)
St. Johns River	Tidal freshwater area north of Lake George	Williams et al. (1975)

CAPE FEAR RIVER ESTUARY - During the period 1963 through 1965, young blueback and American shad exhibited the same general distribution patterns in the Northeast Cape Fear, Black, and Cape Fear Rivers. Shad occurred further upstream in some cases. Blueback were found on the nursery areas (Table 3.8-3) from July through November at mean lengths ranging from 41.3 to 64.3 mm FL. Seaward migration was stimulated by the first significant decrease in water temperature and increase in water level during October or November. Water temperatures ranged from 11.7 to 31.7 C, dissolved oxygen 2.4 to 10.0 ppm, pH 5.2 to 6.8, and alkalinity five to 32 ppm during their stay on the nursery grounds (Davis and Cheek 1966).

NORTHEAST CAPE FEAR RIVER - Juveniles were found throughout the river up to Holly Shelter Creek and in most major tributaries from July through December 1976. Major abundance occurred in tributaries, not in the mainstem. Peak abundance was in November, and migration from the system occurred in October and November (Sholar 1977b). Data collected from 1977 to 1979 exhibited similar trends (Fischer 1980).

CAPE FEAR RIVER - Juvenile blueback were found throughout the Cape Fear River upstream from the Interstate 95 bridge at Fayetteville. Greatest abundance occurred in the tributaries. Peak abundance in 1977 was in September with emigration in late November. Peak abundance in 1978 occurred in July with emigration in October and November. The 1979 peak abundance occurred in August (Fischer 1980).

ALTAMAHA RIVER - Juveniles are collected in all zones of the river (Smith 1968), although temperature and salinity apparently affect their distribution (Street 1970). Young blueback arrive in the estuary about the same time as hickory shad but by July move back upstream to areas of tidal freshwater (RM 11 to 30), which is the primary nursery area (Street 1970). Juveniles congregate in the lower section of the estuary in August and September (Godwin and Adams 1969, Street 1970) and emigrate from the system following a drop in temperature in October to offshore areas in November (Godwin and Adams 1969).

ST. JOHNS RIVER - Beginning in March or April, juveniles move off the spawning grounds and into the tidal freshwater area north of Lake George, which is the principal nursery area during summer and fall. Juveniles

penetrated further downstream in the nursery area in 1973 than in 1972, perhaps because flow rates were higher in 1973. Juveniles begin moving downstream and out of the river when water temperature drops in autumn or early winter (Williams et al. 1975).

3.8.8.2 Adult Migration and Local Movement

OFFSHORE NORTH CAROLINA - During spring 1977, blueback herring were collected offshore from Cape Fear north to the mouth of Chesapeake Bay. The inshore zone (0 to 18.3 m deep) was the primary habitat of adult bluebacks; 93.3% of all adults were captured in this area (Loesch et al. 1977). Historically, February and March are periods of maximum abundance offshore North Carolina, but in 1978 blueback were collected only sporadically. Most were distributed from 18.4 km NNE of Cape Hatteras Lighthouse to the Chesapeake Bay mouth (Johnson et al. 1978). The midshore zone (19.8 to 36.0 m deep) contained 70.9% of all blueback offshore. This offshore movement was due probably to the extremely cold temperatures in shallow, inshore waters that year (Johnson et al. 1978).

NEW RIVER - Sholar (1975) reported that the first adults entered the New River in January with peak abundance in the freshwater zone in April. In 1974, adults were found upstream to the lower channelized section of the river. Ripe adults were observed but none were taken in tributaries and by April none were present in the river. In 1975, blueback adults were found in swamp areas below the channelized portion of the river and in the Northeast, Little Northeast, Blue, and Hawkins Creeks (Sholar 1975).

WHITE OAK RIVER - In 1974, adult blueback were found upstream to Quarry Lakes (Martin Marietta Corporation) from January through May, but none were observed in tributaries. In 1975, the run of adult bluebacks was twice the size of the previous year. Adults were found in Quarry Lakes, and Hunter, Webb, Grant, and Holston Creeks (Sholar 1975).

CAPE FEAR RIVER - Adult blueback were found in February and remained until May, with peak abundance in April. Adults were collected from Walden Creek in the lower Cape Fear River to Brown's Creek just downstream from Lock and Dam No. 2, and in most tributaries (Fischer 1980).

SANTEE-COOPER SYSTEM - Blueback tagged and released in the Santee River near Jamestown migrated upstream to the Wilson Dam sanctuary. The abundance of blueback at Wilson Dam is due to the Santee River blueback run rather than fish displaced from the Cooper River via Lakes Moultrie and Marion (Curtis 1976). The Santee River run of blueback occurred when water temperatures ranged between 12 and 20 C (Bulak and Curtis 1978).

ST. JOHNS RIVER - The blueback herring migration begins at Welaka in late December and continues into late March or early April, with peak migration from early January to mid-March. Larger blueback (both sexes) tend to migrate early in the season, with mean length decreasing as the season progresses. Migrating bluebacks apparently receive little food during their river migration. Volumetrically there was very little in their stomachs, but numerically there were many small crustaceans (Williams et al. 1975).

3.8.8.3 Responses to Stimuli

TEMPERATURE - Migration activity is apparently influenced by temperature. Johnson et al. (1978) reported movement of bluebacks in offshore North Carolina waters from normal inshore areas to the midshore (mid-depth) zone, probably due to the extremely cold temperatures during winter in shallow offshore habitats. Santee River bluebacks begin their spawning run earlier than Cooper River adults and the run is of shorter duration; this is due to the fact that water released from Pinopolis Dam tend to maintain Cooper River water temperatures cooler than Santee River temperatures (Bulak and Curtis 1978).

LIGHT - Feeding was observed to occur only during daylight hours (Marcy 1969).

3.8.9 Population

3.8.9.1 Sex Ratio

OFFSHORE NORTH CAROLINA - Male to female sex ratios were variable by month during 1978. Males outnumbered females during February (1:0.89) and March (1:0.97), and females outnumbered males during April (1:2.89); the overall sex ratio was 1:1.02 (Johnson et al. 1978).

ALBEMARLE SOUND - The male to female ratio was 1.6:1 in 1975 (Holland et al. 1975); 1.09:1 in 1977 (Loesch et al. 1977), and 1.5:1 in 1978 (Johnson et al. 1978).

NEUSE-TRENT SYSTEM - Males outnumbered females 1.55:1 in 1976 (Marshall 1977).

WHITE OAK RIVER - During 1974-75, the sex ratio of blueback herring was 0.88:1 (Sholar 1975).

NORTHEAST CAPE FEAR RIVER - Females outnumber males in this system. The sex ratio was 1:2.3 in 1976 (Sholar 1977b), 1:1.6 in 1977, 1:1.96 in 1978, and 1:2.8 in 1979 (Fischer 1980).

CAPE FEAR RIVER - Male blueback slightly outnumbered females in 1978 (1.1:1) but were slightly outnumbered by females in 1979 (1:1.2) (Fischer 1980).

SANTEE RIVER - The sex ratio in 1977 was 1:1 (Bulak and Curtis 1978).

ST. JOHNS RIVER - The mean male to female sex ratio was 1:1.8 in 1972 and 1:1.2 in 1973 (Williams et al. 1975).

3.8.9.2 Age Composition

With the exception of the Cooper River and the St. Johns River, blueback herring populations along the Southeast Atlantic coast are comprised mainly of age IV and V adults (Table 3.8-4). The Cooper River population is dominated by age III and IV adults, and the St. Johns River population is dominated by age classes V and VI.

3.8.9.3 Size Composition

Female blueback herring are larger than males of similar age (Table 3.8-5). Cooper River blueback appear to be larger in size than blueback in other river systems.

3.8.9.4 Abundance and Population Status

Commercial landings of blueback herring in North Carolina have been in decline since 1969, and Florida landings are no longer reported. South Carolina imposed a quota on commercial landings in an attempt to reverse population decline. Georgia does not exploit blueback herring commercially, although some are taken incidental to American shad and hickory shad.

The status of blueback herring populations in river systems within Region 4 was estimated from responses to the questionnaire returned by various

State and Federal agencies (Section 4). Blueback herring populations appear to be declining throughout North Carolina (Table 3.8-6). Responses from South Carolina representatives indicate blueback stocks are stable, with Cooper River stocks increasing due to a stocking program. Georgia responses indicate that the status of blueback herring populations is not known, apparently due to lack of commercial interest. Blueback populations in Florida rivers have been declining for years. Factors possibly important in contributing to the decline of certain populations are presented in Table 3.8-7. Overfishing by offshore foreign trawlers is believed by many to have caused the demise of North Carolina stocks (McCoy 1976).

3.8.9.5 Factors Affecting Reproduction and Recruitment

Recruitment to the spawning stock begins at age three in most populations. Unlike American shad adults, which die after spawning in Southeast waters, blueback populations rely on repeat spawners to maintain population levels. The inshore North Carolina fishery is based on exploitation of sexually-mature adult blueback herring. Overfishing these populations results in cropping older individuals, thus affecting annual spawning potential. The offshore North Carolina fishery was established in 1967 as a trawl fishery, and has involved foreign fishermen from various countries. The offshore fishery relies on sexually-immature blueback herring, and the two fisheries combined evidently caused - or played an important role in - the demise of North Carolina blueback populations.

3.8.9.6 Mortality

Estimated mortality of blueback herring in Albemarle Sound was 60% in 1977 (Loesch et al. 1977) and 41% in 1978 (Johnson et al. 1978).

3.8.10 Predator-Prey Relationships

No information available.

3.8.11 Diseases

Ergasilus clupeidarum sp. n. is a gill parasite of blueback herring in Southeast U.S. waters (Johnson and Rogers 1972). A few blueback herring in the St. Johns River were externally parasitized by *Lernaea* sp. (Williams et al. 1975).

Table 3.8-4. Age composition (%) of blueback herring populations in river systems within Region 4. M = males; F = females; C = sexes combined.

RIVER SYSTEM AND YEAR	SEX	AGE CLASS I	II	III	IV	V	VI	VII	VIII	IX	SOURCE(S)
Offshore North Carolina											
1971	C		7	10	38	32	7	4	3		Holland and Yelverton (1973)
Albemarle Sound											
1975	M			7	51	30	10	2	<1	<1	Holland et al. (1975)
	F			2	34	29	25	8	<1	2	
1977	M			<1	30	65	5	<1	<1		Loesch et al. (1977)
	F			0	21	66	10	3	<1		
1978	M			5	49	39	6	<1			Johnson et al. (1978)
	F			<1	40	49	7	4			
Scuppernong River											
1975	M			12	63	25	-				Holland et al. (1975)
	F			4	56	33	7				
1977	M			1	36	62	0				Loesch et al. (1977)
	F			0	24	69	7				
1978	M			9	40	44	7	0			Johnson et al. (1978)
	F			0	30	55	10	5			
Meherrin River											
1975	M				14	44	33	6	1	2	Holland et al. (1975)
	F				3	29	47	16	<1	4	
1977	M				41	54	4	<1	0		Loesch et al. (1977)
	F				24	63	10	2	1		
1978	M			4	63	28	4	1			Johnson et al. (1978)
	F			0	50	42	6	3			

Table 3.5-4. Age Composition (cont'd.).

RIVER SYSTEM AND YEAR	SEX	I	II	III	IV	V	VI	VII	VIII	IX	SOURCE(S)
					AGE CLASS						
Chowan River											
1971	M				22	33	31	14			Holland and Yelverton (1973)
	F				19	47	15	19			
1975	M			5	68	24	3	1			Holland et al. (1975)
	F			2	68	25	4	1			
1977	M				22	66	11	<1	0		Loesch et al. (1977)
	F				14	70	10	5	<1		
1978	M			4	37	49	9	<1			Johnson et al. (1978)
	F			1	31	56	8	4			
Perquimans River											
1975	M				78	17	5	<1			Holland et al. (1975)
	F				71	23	6	0			
Yeopim River											
1975	M			1	54	35	10	0			Holland et al. (1975)
	F			0	47	47	5	[illegible]			
Alligator River											
1977	M				14	81	[illegible]	[illegible]	[illegible]		Loesch et al. (1977)
	F				23	60	12	5	[illegible]		
Edenton Bay											
1975	M			2	59	18	20	<1			Holland et al. (1975)
	F			0	35	26	26	13			
Neuse-Trent System											
1977	M			5	46	39	9	1	0		Marshall (1977)
	F			2	33	45	14	6	2		
1978	M			1	31	47	18	1	0		Hawkins (1979)
	F			1	33	35	26	8	2		

Table 3.8-4. Age Composition (cont'd.).

RIVER SYSTEM AND YEAR	SEX	I	II	III	IV	V	VI	VII	VIII	IX	SOURCE(S)
					AGE CLASS						
New River											
1974-75	M				56	31	13				Sholar (1975)
	F				50	50	-				
White Oak River											
1974-75	M			1	46	45	8	0			Sholar (1975)
	F			0	23	57	18	2			
Northeast Cape Fear River											
1976	M				51	46	3	0			Sholar (1977b)
	F				29	57	13	1			
1978-79	M			1	49	44	5	0			Fischer (1980)
	F			1	36	50	12	1			
Cape Fear River											
1978-79	M			4	35	57	4	0			Fischer (1980)
	F			0	33	35	26	6			
South Santee River											
1978	M	4	8	11	31	45	1				Bulak and Curtis (1978)
	F	-	1	12	27	53	7				
Cooper River											
1974	C		17	30	45	8					Curtis (1974)
1975	C		14	32	48	6					Curtis (1975)
1977	C		1	18	53	28					Curtis (1977)
1978	C		2	7	75	16					Curtis (1978)

Table 3.5-4. Age Composition (cont'd.).

RIVER SYSTEM AND YEAR	SEX	AGE CLASS I	II	II	IV	V	VI	VII	VIII	IX	SOURCE(S)
Wilson Dam, SC											
1979	M			41	26	21	12	0			Bulak et al. (1979)
	F			0	20	33	30	17			
St. Johns River											
1972	M			<1	3	39	45	14	0		Williams et al. (1975)
	F			0	<1	21	52	25	2		
1973	M				17	47	30	5	1		Williams et al. (1975)
	F				10	29	46	13	3		

Table 3.8-5. Size composition (mean fork length in mm) of blueback herring populations in river systems within Region 4. M = males; F = females; C = sexes combined.

RIVER SYSTEM AND YEAR	SEX	AGE CLASS I	II	III	IV	V	VI	VII	VIII	IX	SOURCE(S)
Offshore North Carolina											
1971	C		163	208	219	235	255	270	280		Holland and Yelverton (1973)
Albemarle Sound											
1975	M			229	237	247	251	259	270		Street et al. (1975)
	F			244	248	257	264	270	280		
Chowan River											
1971	M				225	238	238	239			Holland and Yelverton (1973)
	F				236	246	246	254			
Tar River											
1975	M			238	250	258	264	-	-		Pate (1975)
	F			244	255	266	275	279	291		
Neuse-Trent System											
1977	M			236	245	252	260	262	-		Marshall (1977)
	F			246	253	260	269	275	285		
1978	M			241	252	257	264	269	-		Hawkins (1979)
	F			250	258	267	274	281	289		
New River											
1974-75	M				233	250	268				Sholar (1975)
	F				246	249	-				
White Oak River											
1974-75	M			219	237	247	249	-			Sholar (1975)
	F			-	242	258	265	280			

Table 3.8-5. Size Composition (cont'd.).

RIVER SYSTEM AND YEAR	SEX	I	II	III	IV	V	VI	VII	VIII	IX	SOURCE(S)
					AGE CLASS						
Northeast Cape Fear River											
1976	M				242	247	264	-			Sholar (1977b)
	F				249	259	275	275			
1978-79	M			240	255	265	278	-			Fischer (1980)
	F			242	263	275	286	295			
Cape Fear River											
1978-79	M			228	252	259	287	-			Fischer (1980)
	F			-	254	272	280	290			
Cooper River											
1974	C		241	257	297	325					Curtis (1974)
1975	C		236	269	297	323					Curtis (1975)
1977	C		267	277	282	290					Curtis (1977)
1978	C		251	274	297	328					Curtis (1978)
St. Johns River											
1972	M			207	231	236	242	244	-		Williams et al. (1975)
	F			-	224	245	252	255	256		
1973	M				221	231	242	248	254		Williams et al. (1975)
	F				226	238	254	258	258		

Table 3.8-6. Status of blueback herring, Alosa aestivalis, in river systems within Region 4 based on questionnaire responses to question VI-2. S = response from marine representative; F = response from freshwater representative.

RIVER SYSTEM	STATUS
NORTH CAROLINA	
Currituck Sound	Declining (S)
Albemarle Sound	Declining (SF)
North R.	Declining (S)
Pasquotank R.	Declining (S)
Little R.	Declining (S)
Perquimans R.	Declining (S)
Yeopim R.	Declining (S)
Chowan R.	Declining (SF)
Meherrin R.	Declining (S)
Roanoke R.	Declining (SF)
Cashie R.	Declining (S)
Scuppernong R.	Declining (S)
Alligator R.	Declining (S)
Pungo R.	Not known (S)
Pamlico R.	Not known (S)
Tar R.	Stable (S) or Declining (SF)
Neuse R.	Stable (S) or Declining (SF)
Trent R.	Stable or declining (S)
North R.	Not known (S)
Newport R.	Not known (S)
White Oak R.	Not known (S)
New R.	Threatened (S)
Cape Fear R.	Stable (S) or Declining (SF)
Northeast Cape Fear R.	Stable (S) or Declining (SF)
Black R.	Not known (S)
Pee Dee R.	Declining (F)
SOUTH CAROLINA	
Waccamaw R.	Stable (SF)
Little Pee Dee R.	Not known (F)
Great Pee Dee R.	Stable (SF)
Black R.	Stable (SF)
Santee R.	Stable (SF)
Cooper R.	Stable (S), Increasing (F)
Ashley R.	Stable (S), Not known (F)
Edisto R.	Stable (S), Not known (F)
Ashepoo R.	Stable (S), Not known (F)
Combahee R.	Stable (S), Not known (F)
Sampit R.	Stable (SF)
Salkehatchie R.	Not known (F)
Savannah R.	Stable (S), Not known (F)
Lynches R.	Stable (S)

Table 3.8-6. Blueback herring (cont'd.).

RIVER SYSTEM	STATUS
GEORGIA	
Savannah R.	Not known (SF)
Ogeechee R.	Not known (SF)
Altamaha R.	Not known (SF)
Oconee R.	Not known (F)
Satilla R.	Not known (SF)
Ocmulgee R.	Not known (F)
St. Marys R.	Not known (SF)
FLORIDA (Atlantic coast)	
St. Marys R.	Not known (S)
Nassau R.	Not known (S)
St. Johns R.	Declining (S)
Pellicer Cr.	Not known (S)
Moultrie Cr.	Probably never present ([illegible])
Tomoka R.	Declining (S)

Table 3.8-7. Factors possibly important or very important in contributing to the decline of certain populations of blueback herring, *Alosa aestivalis*, within Region 4 based on questionnaire responses to question I. S = response from marine representative; F = response from freshwater representative; C = response from other agencies.

NORTH CAROLINA

- Channelization (FC)
- Dredge and fill projects (F)
- Dams and impoundments (FC)
- Industrial water intakes (FC)
- Location of industrial discharges (FC)
- Chemical pollution (F)
- Turbidity (F)
- Low oxygen levels (FS)
- Sewerage outfalls (C)
- Inadequate fishway facilities (F)
- Inadequate control of water release from dams (C)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)
- Poor food availability (F)
- Spawning areas too accessible to fishermen (C)
- Poor water quality (FSC)

SOUTH CAROLINA

- Dams and impoundments (S)
- Inadequate fishway facilities (S)
- Reduction in spawning habitats (S)
- Poor water quality (S)

GEORGIA

- Inadequate information (FS)

FLORIDA

- Channelization (S)
- Industrial water intakes (S)
- Low oxygen levels (S)
- Sewerage outfalls (S)
- Reduced freshwater input to estuaries (S)
- Reduction in spawning habitats (S)
- Reduction in nursery areas (S)
- Poor food availability (S)
- Spawning areas too accessible to fishermen (S)
- Poor water quality (S)

3.8.12 Exploitation

3.8.12.1 Gear

NORTH CAROLINA - Blueback herring are exploited by anchor gill nets, drift gill nets (Roanoke River only), haul seines, and pound nets (Pate 1974). Pound nets presently produce about 95% of the total yearly catch (McCoy 1976).

SOUTH CAROLINA - Principal commercial gear used to exploit blueback are haul seines (Bulak et al. 1979) and dip nets (McCoy 1976).

GEORGIA - Commercial fisheries in Georgia are not directed toward exploitation of blueback stocks. Incidental catches are taken by shad fishermen with large-mesh gill nets.

FLORIDA - In 1972 and 1973, only one haul seine that captured blueback herring was operating on the St. Johns River. The net was a 306 m commercial herring seine 131 meshes deep, and was constructed of stretched mesh of sizes ranging from 6.03 to 6.35 cm. Blueback are also captured in some pound nets. There is no sport fishery for blueback, although some are caught incidentally by sportfishermen trolling for American shad (Williams et al. 1975).

3.8.12.2 Fishing Areas

NORTH CAROLINA - Most commercial fishing for blueback herring occurs in the sounds and tributaries of North Carolina waters.

SOUTH CAROLINA - Commercial haul seines and dip net fisheries operate at Wilson Dam.

GEORGIA - No commercial exploitation.

FLORIDA - Blueback are taken by commercial haul seine in the Palatka to Lake George area of the St. Johns River, and some are captured by pound nets in this area (Williams et al. 1975).

3.8.12.3 Fishing Seasons

NORTH CAROLINA - Peak pound net catches generally occur during the last half of April, and the catch is comprised largely of spent fish emigrating from the upstream spawning grounds (McCoy 1976). Effort is concentrated during spring spawning runs.

SOUTH CAROLINA - Effort is concentrated during spring spawning runs.

GEORGIA - There are no official seasons for blueback herring.

FLORIDA - Effort is concentrated during the spring spawning run.

3.8.12.4 Effort

Blueback herring are reported in the official commercial catch statistics as "alewife". This heading also includes alewife, Alosa pseudoharengus, which is not found in abundance south of the Cape Fear River, North Carolina. "Alewife" catches reported from Gulf coast Florida waters refer to the Alabama shad, Alosa alabamae.

NORTH CAROLINA - Commercial fishing statistics for blueback herring also include alewife. The most recent peak in river herring landings occurred in 1969, when 19,762,000 pounds (Table 3.8-8) representing 10.54% of total finfish landed (Table 3.8-9) were harvested from North Carolina waters. Dockside value of 1969 landings was $304,000 (Table 3.8-10), which comprised 6.02% of total finfish dockside value for that year (Table 3.8-11). Commercial catches have been in decline since 1969. From 1 December 1966 to 5 June 1967, 2,853,051 herring were caught by various special devices in North Carolina waters. The majority (76%) of herring caught were landed by dip net (including bow and skim nets); total weight was 2,171,513 pounds. Commercial landings were also taken by anchored gill nets (434,250 pounds) and drift gill nets (247,288 pounds). Catch (in pounds) by watershed was:

Chowan River	834,757
Roanoke River	602,589
Albemarle Sound	267,677
Tar River	312,291
Pamlico River	332,228
Neuse River	351,577
Northeast Cape Fear River	17,120
Cape Fear River	119,855
Lumber River	299
Pee Dee River	143
Minor Ocean Tributaries	14,585

(Baker 1968).

McCoy (1976) summarized the effects of offshore foreign fishing on North Carolina river herring stocks. " The

inshore fishery for river herring is of historical importance, particularly in North Carolina and Virginia. The (offshore) trawl fishery has existed only since 1967 and has apparently resulted in a decrease in total harvest. ICNAF data show that river herring are harvested in ICNAF areas 4 and 5 and statistical area 6. River herring which spawn in the streams tributary to these areas apparently mix on the high seas during the summer and fall... and are subjected to high seas fisheries without regard to their nation or stream of origin..." Since 1967, foreign fleets have harvested U.S. offshore herring stocks in quantities ranging from four to 44% of the total harvest reported (Table 3.8-12).

SOUTH CAROLINA - The South Carolina dip net fishery is concentrated mainly in the Cooper River. Data on landings from this fishery were obtained from the South Carolina Wildlife and Marine Resources Department by McCoy (1976). Landings, reported in metric tons, were:

1969	1,112
1970	145
1971	629
1972	449
1973	165
1974	40
1975	8

A fire at Jeffries hydroelectric station upstream from the Cooper River fishery led to minimal water releases from Pinopolis Dam, causing reduced attraction flow and a much-reduced run of river herring in 1970 (McCoy 1976).

GEORGIA - There is no commercial or recreational fishing effort for blueback herring.

FLORIDA - Fishing effort for blueback herring in the St. Johns River is quite low. Only one haul seine was operated in 1972 and 1973, and some are captured in pound nets in the same area. There is no sportfishery for blueback, although some are taken incidentally by American shad fishermen (Williams et al. 1975).

3.8.13 Protection and Management

3.8.13.1 North Carolina

The status of blueback populations in North Carolina and recommendations for management were presented by Loesch et al. (1977) and Johnson et al. (1978).

Table 3.8-8. "Alewife" or river herring landed (thousands of pounds).

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA	TOTAL
1880	15520	400	125	10	.	.	.	.	16055
1887	23747	.	25	.	.	.	.	.	23772
1888	20451	.	24	.	.	.	.	.	20475
1889	19316	37	36	.	.	.	.	.	19389
1890	22112	29	24	10	.	.	.	.	22175
1897	20839	2	25	41	.	.	.	.	20907
1902	15173	.	22	406	.	.	.	.	15601
1908	12530	.	32	1220	.	.	.	.	13782
1918	17356	10	.	692	.	.	.	.	18058
1923	8989	.	.	1062	.	.	.	.	10051
1927	13911	.	.	213	.	.	.	.	14124
1928	7808	2	.	370	.	.	.	.	8180
1929	10768	.	.	408	.	.	.	.	11176
1930	9839	2	.	366	.	.	.	.	10207
1931	7994	.	.	321	.	.	.	.	8315
1932	6584	.	.	80	.	.	.	.	6664
1934	14897	.	.	215	.	.	.	.	15112
1936	11929	.	.	232	.	.	.	.	12161
1937	5816	.	.	232	.	.	.	.	6048
1937	5816	.	.	400	.	.	.	.	6216
1938	11219	.	.	392	.	.	.	.	11611
1939	7714	.	.	320	.	.	.	.	8034
1940	8708	.	.	408	.	.	.	.	9116
1945	8022	.	.	428	.	.	.	.	8450
1950	6423	.	.	358	42	.	.	.	6823
1951	12535	.	.	514	22	.	.	.	13071
1952	6510	.	.	278	97	.	.	.	6885
1953	13842	.	.	.	36	.	.	.	13878
1954	12758	.	.	51	39	.	.	.	12848
1955	12648	.	.	57	38	.	.	.	12743
1956	12554	.	.	77	18	.	.	.	12649
1957	11773	.	.	30	114	.	.	.	11917
1958	14914	.	.	127	48	.	.	.	15089
1959	14154	.	.	16	49	.	.	.	14219
1960	12815	.	.	26	162	.	.	.	13003
1961	11951	.	.	2	281	.	.	.	12234
1962	14302	.	.	.	1001	.	.	.	15303
1963	15100	.	.	23	836	.	.	.	15959
1964	7561	.	.	2	433	.	.	.	7996
1965	12826	2760	.	21	406	.	.	.	16013
1966	12519	2817	.	1	240	.	.	.	15577
1967	18486	2802	.	.	163	.	.	.	21451
1968	15525	2820	.	.	99	.	.	.	18444
1969	19762	.	.	.	224	.	.	.	19986
1970	11521	100	.	.	251	.	.	.	11872
1971	12722	718	.	.	420	.	.	.	13860
1972	11237	297	.	.	128	.	.	.	11662
1973	7926	433	.	.	168	.	.	.	8527
1974	6210	87	.	.	179	.	.	.	6476
1975	5952	18	.	2	.	.	.	.	5972
1976	6401	67	.	.	.	.	.	.	.
1977	8524	282	.	.	.	.	.	.	.
1978	6607	196	.	.	.	.	.	.	.
1979	5119	334	.	.	.	.	.	.	.
1980	6219	.	.	.	.	.	.	.	.
1981	4754	.	.	.	.	.	.	.	.

Table 3.8-9. Pounds landed (%) of "alewife" or river herring in the total commercial catch of finfish by state.

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA
1880	.	.	.	.	.	.	.	.
1887	.	.	.	.	.	.	.	.
1888	.	.	.	.	.	.	.	.
1889	.	.	.	.	.	.	.	.
1890	.	.	.	.	.	.	.	.
1897	.	.	.	.	.	.	.	.
1902	.	.	.	.	.	.	.	.
1908	.	.	.	.	.	.	.	.
1918	.	.	.	.	.	.	.	.
1923	.	.	.	.	.	.	.	.
1927	.	.	.	.	.	.	.	.
1928	.	.	.	.	.	.	.	.
1929	.	.	.	.	.	.	.	.
1930	.	.	.	.	.	.	.	.
1931	.	.	.	.	.	.	.	.
1932	.	.	.	.	.	.	.	.
1934	.	.	.	.	.	.	.	.
1936	.	.	.	.	.	.	.	.
1937	.	.	.	.	.	.	.	.
1937	.	.	.	.	.	.	.	.
1938	.	.	.	.	.	.	.	.
1939	3.59	.	.	0.14	.	.	.	.
1940	5.41	.	.	0.24	.	.	.	.
1945	4.49	.	.	0.19	.	.	.	.
1950	4.15	.	.	0.77	0.09	.	.	.
1951	9.01	.	.	0.50	0.04	.	.	.
1952	2.72	.	.	0.19	0.16	.	.	.
1953	8.37	.	.	.	0.07	.	.	.
1954	6.51	.	.	0.04	0.54	.	.	.
1955	5.96	.	.	0.12	0.03	.	.	.
1956	4.41	.	.	0.04	0.04	.	.	.
1957	5.45	.	.	0.07	0.70	.	.	.
1958	5.45	.	.	0.30	0.07	.	.	.
1959	4.43	.	.	0.22	0.06	.	.	.
1960	5.27	.	.	0.26	0.24	.	.	.
1961	4.50	.	.	0.00	0.42	.	.	.
1962	8.73	.	.	.	1.46	.	.	.
1963	6.43	.	.	0.04	1.22	.	.	.
1964	3.62	.	.	0.02	0.67	.	.	.
1965	6.31	13.44	.	0.03	0.64	.	.	.
1966	5.52	26.44	.	0.03	0.37	.	.	.
1967	9.10	38.79	.	.	0.24	.	.	.
1968	7.50	31.34	.	.	0.16	.	.	.
1969	10.54	.	.	.	0.77	.	.	.
1970	7.45	2.12	.	.	0.41	.	.	.
1971	10.67	13.04	.	.	0.46	.	.	.
1972	7.26	5.44	.	.	0.30	.	.	.
1973	6.64	11.14	.	.	0.25	.	.	.
1974	3.38	3.14	.	.	0.35	.	.	.
1975	2.70	1.51	.	0.03	.	.	.	.
1976	3.11	.	.	.	.	.	.	.
1977	3.53	.	.	.	.	.	.	.
1978	2.45	.	.	.	.	.	.	.
1979	1.45	.	.	.	.	.	.	.

Table 3.8-10. Dockside value of "alewife" or river herring (thousands of dollars).

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA	TOTAL
1939	77	.	.	2	.	.	.	.	79
1940	109	.	.	2	.	.	.	.	111
1945	177	.	.	9	.	.	.	.	186
1950	128	.	.	11	1	.	.	.	140
1951	129	.	.	10	0	0	.	.	139
1952	81	.	.	14	5	.	.	.	100
1953	138	.	.	.	2	.	.	.	140
1954	127	.	.	2	1	.	.	.	130
1955	130	.	.	1	1	.	.	.	132
1956	135	.	.	2	1	.	.	.	138
1957	118	.	.	1	3	.	.	.	122
1958	149	.	.	4	2	.	.	.	155
1959	142	.	.	1	2	.	.	.	145
1960	128	.	.	1	8	.	.	.	137
1961	120	.	.	1	11	.	.	.	132
1962	143	.	.	.	40	.	.	.	183
1963	151	.	.	1	25	.	.	.	177
1964	77	.	.	0	17	.	.	.	94
1965	133	55	.	1	15	.	.	.	204
1966	134	56	.	1	7	.	.	.	198
1967	318	56	.	.	5	.	.	.	379
1968	235	48	.	.	3	.	.	.	286
1969	304	30	.	.	9	.	.	.	343
1970	194	2	.	.	10	.	.	.	206
1971	203	12	.	.	16	.	.	.	231
1972	196	6	.	.	5	.	.	.	207
1973	213	13	.	.	9	.	.	.	235
1974	247	3	.	.	11	.	.	.	261
1975	215	1	.	1	.	.	.	.	217
1976	337	5	.	.	.	.	.	.	.
1977	422	21	.	.	.	.	.	.	.
1978	237	16	.	.	.	.	.	.	.
1979	314	23	.	.	.	.	.	.	.
1980	444	.	.	.	.	.	.	.	.
1981	317	.	.	.	.	.	.	.	.

Table 3.8-11. Dockside value (%) of "alewife" or river herring in the total commercial catch of finfish by state.

YEAR	NC	SC	GA	FL(E)	FL(W)	AL	MS	LA
1939	5.07	.	.	0.12	.	.	.	.
1940	7.19	.	.	0.06	.	.	.	.
1945	4.74	.	.	0.07	.	.	.	.
1950	3.41	.	.	0.42	0.02	.	.	.
1951	4.01	.	.	0.26	0.01	0.01	.	.
1952	[illegible]	.	.	0.25	0.07	.	.	.
1953	3.37	.	.	.	0.03	.	.	.
1954	[illegible]	.	.	[illegible]	[illegible]	.	.	.
1955	3.27	.	.	[illegible]	[illegible]	.	.	.
1956	[illegible]	.	.	[illegible]	[illegible]	.	.	.
1957	[illegible]	.	.	[illegible]	0.05	.	.	.
1958	[illegible]	.	.	0.13	[illegible]	.	.	.
1959	[illegible]	.	.	0.03	[illegible]	.	.	.
1960	3.32	.	.	0.03	0.13	.	.	.
1961	2.77	.	.	0.01	[illegible]	.	.	.
1962	[illegible]	.	.	.	[illegible]	.	.	.
1963	3.44	.	.	0.01	[illegible]	.	.	.
1964	1.70	.	.	[illegible]	0.23	.	.	.
1965	2.63	[illegible]	.	0.01	0.19	.	.	.
1966	2.67	[illegible]	.	0.01	[illegible]	.	.	.
1967	[illegible]	[illegible]	.	.	0.06	.	.	.
1968	5.11	[illegible]	.	.	0.03	.	.	.
1969	6.02	[illegible]	.	.	[illegible]	.	.	.
1970	4.25	[illegible]	.	.	[illegible]	.	.	.
1971	[illegible]	[illegible]	.	.	[illegible]	.	.	.
1972	[illegible]	[illegible]	.	.	[illegible]	.	.	.
1973	2.47	[illegible]	.	.	0.07	.	.	.
1974	[illegible]	[illegible]	.	.	0.06	.	.	.
1975	1.74	[illegible]	.	0.01	.	.	.	.
1976	[illegible]	.	.	.	.	.	.	.
1977	[illegible]	.	.	.	.	.	.	.
1978	1.13	.	.	.	.	.	.	.
1979	[illegible]	.	.	.	.	.	.	.

"Virginia and North Carolina are the center of river herring production for the Atlantic coast. As such, condition of their stocks and fisheries determines the overall condition of the total fishery. Considering the two States together, the fishery has not significantly recovered from the decline apparently caused by overfishing on the high seas by foreign vessels. Reproductive success of river herring in Virginia has declined since the mid-1960s, and in the Albemarle Sound area of North Carolina since 1973. In Virginia the 1972 year class was decimated, apparently due to Tropical Storm Agnes. The 1973 year class failed, as well, for unknown reasons. No reasons can be given for poor year classes in the Albemarle Sound area, either. Reproductive failures, however, have been far more drastic in Virginia than in North Carolina" (Johnson et al. 1978).

"In order to obtain added protection for river herring stocks, the United States negotiated bilateral agreements with Poland, Romania, and the USSR during 1975 and 1976. These agreements have been briefly described by Holland and Keefe (1977). During the 1977 season, only the agreement with the Soviet Union was in effect. The restrictions of this agreement relative to this report were: 1) Soviet vessels will refrain from fishing during February and March in an area from Little Machipongo Inlet (Lat. 37^{o} 30'N) south to Ocracoke Inlet (Lat. 35^{o} 0'N) offshore to approximately Long. 74^{o} 48'W; 2) Vessels shall limit catches of river herring to incidental catches only, and to 210 metric tons (231.5 tons) for all vessels and to 10 metric tons (11.0 tons) per vessel; 3) Vessels shall cease fishing operations for the year when the 210 metric ton limit is reached, and any individual vessel reaching the 10 metric ton limit shall refrain from fishing for the remainder of the year" (Loesch et al. 1977).

"With the implementation of the Fishery Conservation and Management Act of 1976 (Public Law 94-265) on 1 March 1977, Governing International Fisheries Agreements (GIFA) were in effect with all nations fishing within the United States Fishery Conservation Zone. Under the agreements foreign nations must abide by regulations published by National Marine Fisheries Service (NMFS) from time to time in the Federal Register" (Loesch et al. 1977).

"National Marine Fisheries Service statistics indicate that a total of 28.3 metric tons (MT) of river herring was taken by foreign vessels along the Atlantic

coast during 1978, all as by-catch by the Soviet Union and Spain. It is significant to note that the first seizures of foreign vessels for violations of U.S. fishing regulations under the Fishery Commission and Management Act were for excessive catches of river herring. Since the yearly total was only 28.3 MT when the by-catch allocation was 453 MT, it is obvious that the foreign vessels are able to avoid river herring, and that future allocations do not need to be so large. Considering the facts that river herring stocks are still quite depressed and that foreign vessels are able to operate successfully with very little river herring by-catch, it is recommended that the regional fishery management councils work with the Secretary of Commerce to reduce the river herring by-catch allocation from 453 MT in 1978 to 100 MT or less beginning in 1980" (Johnson et al. 1978).

3.8.13.2 South Carolina

In 1975, South Carolina imposed restrictive regulations on the Cooper River herring fishery. A limit of one hundred pounds of herring per boat per day was imposed in order to protect the dwindling brood stock. The new regulation severely restricted the commercial fishermen but had little or no effect on the live-bait fishery (Curtis 1976).

Bulak and Curtis (1978) reported that large numbers of herring passed into the upper Santee-Cooper lakes at the Pinopolis Navigation Lock at the head of the Cooper River. They pointed out that when the Santee-Cooper Rediversion Project is completed, herring will have to travel 92 km up the Santee River to reach the new fish lift. Presently the distance is 80 km to reach the Pinopolis Lock. Future management activities must decide rationally how many herring can be harvested from the Santee River stock to insure successful passage of herring at the proposed fish lift (Bulak and Curtis 1978).

3.8.13.3 Georgia

No information available.

3.8.13.4 Florida

Williams et al. (1975) reported that it was not practical to manage blueback herring populations at the time at which their project was completed.

Table 3.8-12. Catch of river herring (blueback and alewife) in the inshore fishery of North Carolina and in ICNAF subarea 6 by various countries. Catch is reported in metric tons, round weight (One metric ton = 2,204.6 pounds)(adapted from McCoy 1976).

	INSHORE		OFFSHORE							
YEAR	North Carolina	Total U.S.A.	U.S.S.R	East Germany	Bulgaria	Poland	Romania	Total Foreign	Grand Total	Catch - Percent Foreign
1966	5,680	21,178							21,178	0
1967	8,387	22,201	981					981	23,182	4
1968	7,044	23,649	1,075	126				1,201	24,850	5
1969	8,966	24,352	10,380		570			10,950	35,302	31
1970	5,227	14,888	5,954		746			6,700	21,588	31
1971	5,745	11,799	2,275	5,794	526	819		9,419[1]	21,213	44
1972	5,079	10,609	2,048	2,371	146	407		4,972	15,120[1]	33
1973	3,584	7,640	800	1,036	279	338		2,453	10,093	24
1974	2,817	9,520	238	1,594	574	412	262	3,080	12,590[1]	24
1975	2,678	7,828[2]								

1 (sic)

2 Estimated landings

3.9 Alewife (*Alosa pseudoharengus*)

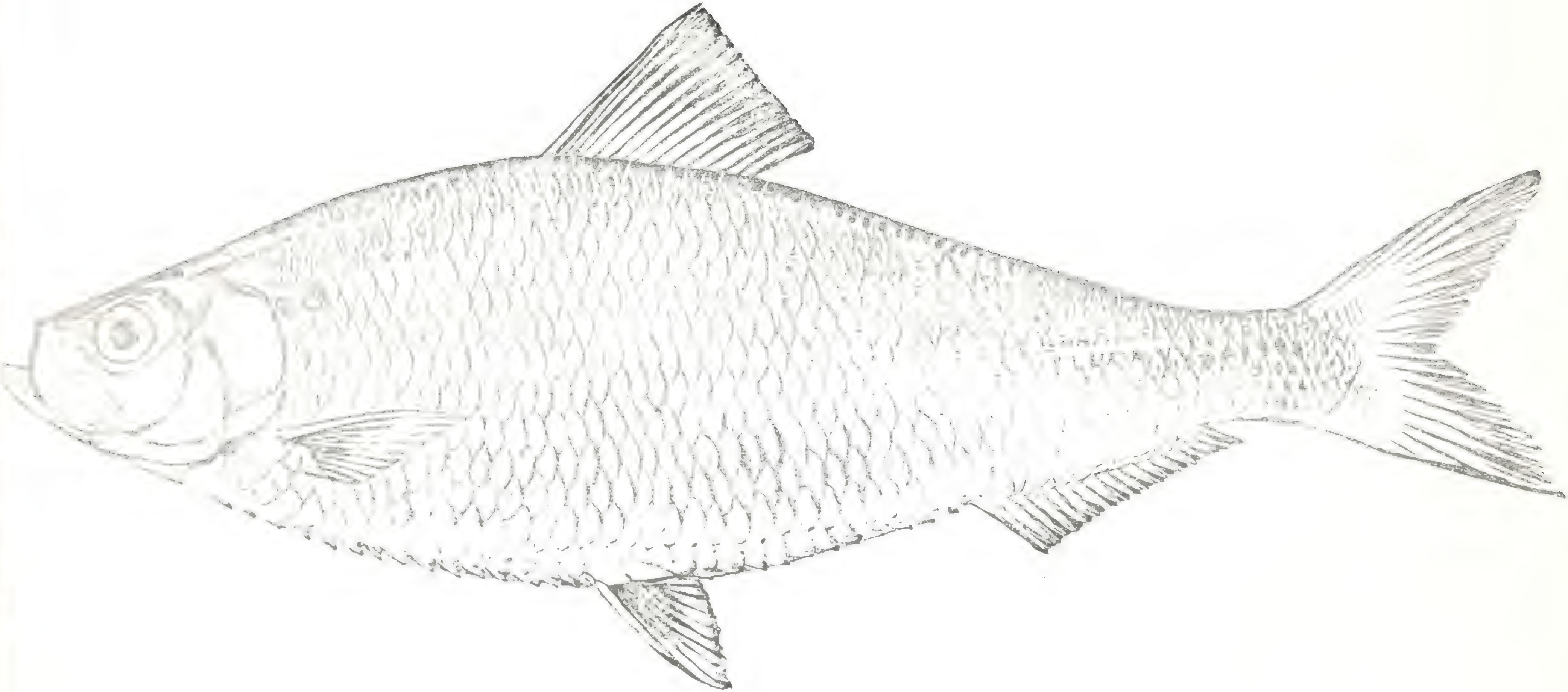
3.9.1 Historical Significance

Alewife - also known as sawbelly, kyak, gaspereau, branch herring, and greyback - reach their northern limit in Newfoundland and their southern limit in South Carolina. Alewife and blueback herring are caught and marketed together as "river herring" and are reported in commercial catch statistics under "alewife." Both species are sold fresh or salted for human consumption, though most are sold as crab bait and fish meal (Pate 1974).

Alewife have great historical importance in the United States. Alewife were utilized by Indians both as food and as fertilizer for crops. The colonists recognized the importance of alewife; the first fishery law passed in Plymouth Colony was known as the Plymouth Colony Fish law and was enacted in 1623 for the protection of the alewife (Belding 1921, cited in Tyus 1971). One of the first studies undertaken by the U.S. Commission of Fish and Fisheries concerned the alewife fishery. Smith (1899) reported that the abundance and cheapness of alewife made them of almost incalculable importance in coastal areas. In 1896, nearly 150,000 alewife were sold by fishermen in fourteen states for food and bait and over 2,500 people were employed in the alewife fisheries in that year (Smith 1899).

Alewife are most abundant in the waters of the Mid-Atlantic and Northeast States. Most life history studies on alewife have been conducted on populations in Northeast Atlantic States and have been summarized in this section.

In North Carolina, alewife and blueback herring are the most abundant anadromous fish species, and greatest abundance is in Albemarle Sound (Pate 1974). In the Chowan and Scuppernong Rivers, herring populations are comprised of 70% blueback and 30% alewife (Pate 1974). The river herring fishery has declined drastically from peak catches in 1967, 1968, and 1969. Although landings have varied historically over a wide range in North Carolina, the recent decline was particularly sharp and was caused by increased landings by the offshore herring fishery (Street 1980). Research by the Division of Marine Fisheries has led to severe restrictions on high seas catches of river herring by foreign vessels (Street 1980). These restrictions are summarized in Section [illegible]. River herring landings in 1979 were the lowest on record and may have been related to water quality problems in the Chowan River and Albemarle Sound (Street 1980). The Lake Mattamuskeet canals bordering



ALEWIFE (_Alosa pseudoharengus_)

the Pamlico and Albemarle Sounds appear to be the southern boundary for alewife in numbers great enough to support a commercial fishery (M.W. Street 1981, pers. comm.). Section 3.8 "Blueback Herring" summarizes commercial fishery information on river herring in North Carolina.

3.9.2 Distribution

3.9.2.1 Range

Alewife range from Newfoundland (Winters et al. 1973) to South Carolina (Berry 1964). There have been reports of alewife from Florida waters, but these records are questionable (McLane 1955). Bean (1883) reported alewife from Florida waters as *Clupea vernalis* and Lonneberg (1894) reported it from the St. Johns River as *Clupea pseudoharengus*. However, studies by McLane (1955) and Williams and Grey (1975) did not locate any specimens of alewife in Florida waters.

3.9.2.2 Eggs

Initially, alewife eggs are demersal and adhesive. Within several hours the adhesive property is lost and the eggs enter the water column (Mansueti 1956, Cooper 1961).

3.9.2.3 Larvae

Alewife larvae remain in the vicinity of the spawning grounds (Hildebrand 1963).

3.9.2.4 Juveniles

Juvenile alewife remain in tidal creek nursery areas and move seaward in late summer and fall, depending on latitude. Some overwinter in estuarine areas, but most go to sea. During their first year in saltwater they tend to remain near the surface (Bigelow and Schroeder 1953).

3.9.2.5 Adults

Alewife is a schooling species. Oceanic movements appear to be restricted to coastal areas close to natal estuaries. Maximum depth is 110 to 145 m and maximum distance from land is about 130 km (Bigelow and Schroeder 1953).

3.9.3 Reproduction

3.9.3.1 Maturity

Most alewife in North Carolina waters mature and enter the fishery by age III or IV.

3.9.3.2 Mating

Cooper (1961) summarized alewife mating behavior. Female alewife swim close to shore followed by a number of males. The act of spawning is accomplished in groups of three or in pairs. One or two males swim side by side with the female. Eggs and sperm are extruded simultaneously. The eggs, broadcast at random, settle and adhere to available substrate (Cooper 1961).

3.9.3.3 Fertilization

Eggs and milt are broadcast randomly in the water column (Cooper 1961).

3.9.3.4 Fecundity

Smith (1907) reported that Potomac River alewife contained an average of 102,800 eggs per female. Bigelow and Schroeder (1953) reported that fecundity ranged from 60,000 to 100,000 eggs per female. Bride Lake and Bride Brook alewife (Connecticut) contained between 48,000 and 360,000 eggs, with a mean of 229,000 eggs per female (Kissil 1969).

3.9.4 Spawning

3.9.4.1 Season and Location

Because blueback herring outnumber alewife in most river systems, it has been difficult to determine the exact season and location for spawning in North Carolina. Marshall (1977) reported spawning runs of alewife from mid-March to mid-April in the Neuse River. Sholar (1975) reported alewife spawning from late March-early April to late May.

Spawning locations in many cases are similar to those of blueback herring (Table 3.9-1). In the Northeast Cape Fear River, a clear separation of spawning grounds is evident. Alewife utilize the area below Lane's Ferry, while blueback occur upriver from that point (Scholar 1975).

3.9.4.2 Temperature

Alewife spawning overlaps with blueback herring spawning; therefore, specific temperature requirements

for alewife are difficult to determine. Most spawning temperatures have been recorded for "river herring" and do not separate the two species. Marshall (1977) reported alewife in spawning condition at temperatures ranging from 15 C to 20.5 C in the Neuse River.

3.9.4.3 Spawning Habitat

Eggs and milt are released over a detritus-covered bottom of attached vegetation, sticks, or other organic matter and occasionally over a hard sand bottom (Cooper 1961) in ponds and sluggish stretches of rivers and streams (Bigelow and Schroeder 1953).

3.9.4.4 Diel Spawning Patterns

In Pausacaco Pond, Connecticut, alewife spawned at all times of the day with no difference in intensity (Cooper 1961).

3.9.5 Life History - Eggs and Larvae

3.9.5.1 Hatching and Growth

The incubation period for fertilized alewife eggs has been determined to be 2.1 days at 28.9 C, 3.7 days at 21.1 C (Edsall 1970), 3.4 to 5 days at 10.0 to 12.2 C (Cianci 1969), six days at 15.6 C (Hildebrand 1963), and about 15 days at 7.2 C (Edsall 1970).

GROWTH - Alewife larvae range from 3.299 to 4.828 mm TL at hatch, averaging 4.096 mm (Cianci 1969). Prolarvae growth is rapid but decreases markedly in postlarvae three days and older (Cianci 1969). Survival of unfed larvae is 2.4 days at 26.7 to 27.8 C, 7.6 days at 14.4 to 15 C, and three to eight days at 10.6 C (Edsall 1970). Duration of the yolk-sac stage is two to five days (Jones et al. 1978). Larvae become juveniles at approximately 20 mm TL (Nordon 1967).

FEEDING - No information available.

3.9.5.2 Hardiness

Little information was available on the hardiness of alewife eggs and larvae for the following factors: salinity, salinity-temperature interaction, acclimation, oxygen, pH, and transport.

Table 3.9-1. Spawning grounds of alewife.

RIVER SYSTEM	LOCATION	SOURCE(S)
Alligator River	Gum Neck Landing; Alligator River SW and NW forks; Alligator Creek; East Lake (lower); Second Creek; Frying Pan; South Lake (middle and upper); Kilkenny Landing; Swan Lake; Cherry Ridge Landing	Loesch et al. (1977)
Cashie River	Hoggard Mill Creek (SR 1301); Wading Place Creek (SR 1514)	Johnson et al. (1978)
Neuse River	Not known; probably utilize the river as far upstream as Contentnea Creek	Hawkins (1979)
White Oak River	Grant Creek	Sholar (1975)
Northeast Cape Fear River	Below Lane's Ferry in lower river	Sholar (1977b)
Cape Fear River	Areas from Mile Board -6 (below Wilmington) to Mile Board 38 (below Lock No. 1)	Fischer (1980)

TEMPERATURE - Alewife eggs will hatch at temperatures ranging from 6.9 to 29.4 C, and optimum hatch occurs at approximately 15 C (Edsall 1970). Fertilized alewife eggs subjected to time-excess temperatures of six to 10 C for 2.5 to 60 minutes (cooling time 60 to 300 minutes) did not have significantly-altered hatching success (Schubel 1974). At incubation temperatures below 10.6 C, 69% of newly-hatched larvae were deformed. Above 10.6 C, the number of deformed larvae dropped to 1.7% (Edsall 1970).

SUSPENDED SEDIMENTS - The hatching success of alewife eggs was not affected by suspended sediments in concentrations of 100 mg l^{-1} or less (Auld and Schubel 1978).

3.9.5.3 Swimming Ability

Prolarvae are positively phototrophic (Mansueti 1956) and swim in spasms toward the surface (Cianci 1969).

3.9.5.4 Chemical Tolerances

No information available.

3.9.5.5 Pressure

No information available.

3.9.6 Life History - Juveniles

3.9.6.1 Nutrition and Growth

FEEDING - Young alewife have feeding habits similar to young blueback herring in the Cape Fear and Northeast Cape Fear Rivers, even though alewife are found only in the tidal areas. The primary food items are cladocerans, copepods, and crustacean eggs. The major portion of insect parts ingested are composed of various dipterans (Davis and Cheek 1966).

GROWTH - Young Neuse River alewife grew from 35 mm in June to 75 mm in August (Hawkins 1979). Juveniles that overwintered in the lower Neuse River ranged from 55 to 95 mm by March (Spitsbergen and Wolff 1974). White Oak alewife grew from 47 mm in July to 81 mm in December (Sholar 1975). Cape Fear River and Northeast Cape Fear River alewife grew at similar rates during summer 1964-65. Sizes ranged from 38 to 59 mm in August (Davis and Cheek 1966).

METABOLISM - No information available.

3.9.6.2 Hardiness

No information was available on the hardiness of juvenile alewife to salinity, salinity-temperature interaction, acclimation, suspended sediments, pH, and transport.

TEMPERATURE - Critical thermal maxima and incipient upper lethal temperature were determined for juvenile alewife collected from Lake Michigan by Otto et al. (1976). Incipient upper lethal limits for young-of-the-year exceeded those for mature alewife by three to six degrees C and increased with acclimation temperature increases. Critical thermal maxima at equivalent acclimation temperatures were not affected by fish age. The preferred temperature for juveniles was consistantly higher than for mature alewife (Otto et al. 1976). Some alewife survived and fed in water of 34.4 to 35.0 C (Dorfman and Westman 1970).

OXYGEN - Juvenile alewife that are engulfed by - or swim into - water with oxygen concentrations as low as 0.5 mg l^{-1} can probably survive for at least five minutes if given access to an area of higher oxygen concentration above 3.0 mg l^{-1} (Dorfman and Westman 1970). Alewives respond to oxygen concentrations below 2.0 mg l^{-1} in the laboratory by moving toward the surface of the test chamber. Apparently they have no instinctive ability to quickly recognize and avoid waters of low oxygen concentration, although they prefer higher oxygen concentrations when placed in a gradient (Dorfman and Westman 1970). The presence of toxic substances, such as heavy metals and oils in water, may decrease concentrations of dissolved oxygen to lethal or sublethal (reduced growth) levels (Dorfman and Westman 1970). At oxygen concentrations lethal to approximately 30% of the population, surviving alewives fed on brine shrimp (in the laboratory) (Dorfman and Westman 1970).

3.9.6.3 Swimming Ability

Juvenile alewives form schools within one to two weeks after hatching (Cooper 1961).

3.9.6.4 Chemical Tolerances

KEPONE - Juvenile alewives collected in the James and Chickahominy Rivers, Virginia, contained average concentrations of 0.58 and 0.50 ppm Kepone in body tissues, values that exceed the action level of 0.3 ppm (Johnson et al. 1978).

3.9.6.5 Pressure

No information available.

3.9.7 Life History - Adults

3.9.7.1 Longevity

Age class IX alewife were collected from populations in Edenton Bay and Meherrin River, North Carolina, in 1975 (Holland et al. 1975).

3.9.7.2 Nutrition and Growth

FEEDING - Adult alewife feed in freshwater only after spawning, and the principle food item is caddis fly - Brachyentrus (Cooper 1961). Stomachs of alewife collected from offshore North Carolina contained unidentified fish remains and zooplankton - amphipods, copepods, isopods, cumaceans, mysids, sagetta, and decapod larvae (Holland and Yelverton 1973).

GROWTH - Holland and Yelverton (1973) estimated length-weight and length-age relationships for alewives collected in waters offshore North Carolina from 1969 to 1971, and from the Chowan River at Tunis from March through May 1971. The relationships were estimated as

FORK LENGTH-WEIGHT

Offshore	$W = 2.42 \times 10^{-6} L^{3.34}$
Chowan Males	$W = 7.49 \times 10^{-6} L^{3.13}$
Chowan Females	$W = 7.78 \times 10^{-6} L^{3.12}$

FORK LENGTH-AGE

Offshore	$A = 190.50\ L^{0.18}$
Chowan Males	$A = 181.40\ L^{0.18}$
Chowan Females	$A = 177.70\ L^{0.22}$
Chowan (Both)	$A = 172.70\ L^{0.22}$

(Holland and Yelverton 1973).

METABOLISM - Body weight loss of migrating adults to Pausacaco Pond, Connecticut, is about 50 g for females and 35.7 g for males. This may be due to increased metabolic rate caused by the warm pond, the energy used to spawn, and the absence of feeding (Cooper 1961). Changes in blood characteristics of alewives could be due to freshwater migration and reproduction: postspawners exhibit a significant reduction in the average concentration of serum proteins and chlorides (Sindermann and Mairs 1961). Analysis of blood lactic acid concentration showed no muscle fatigue in migrating adults passing through a fishway on the Gaspereau River, Nova Scotia (Dominy 1971).

3.9.7.3 Hardiness

Information was not available on the hardiness of alewife adults to salinity, salinity-temperature interaction, acclimation, oxygen, suspended sediments, and transport.

TEMPERATURE - The critical thermal maxima and incipient upper lethal temperature increase with acclimation temperature for mature alewives. The critical thermal maxima at equivalent acclimation temperatures are not affected by fish age. The ultimate lower lethal temperature for adults appears to be below 3 C (Otto et al. 1976).

pH - Adult alewives are indifferent to pH differences as large as 0.8 pH units within a pH range of 6.5 to 7.3 (Collins 1952).

3.9.7.4 Swimming Ability

No information available.

3.9.7.5 Chemical Tolerances

No information available.

3.9.7.6 Pressure

No information available.

3.9.8 Behavior

3.9.8.1 Juvenile Migration and Local Movement

OFFSHORE NORTH CAROLINA - Juveniles predominated offshore North Carolina waters during late fall and winter.

presumably after leaving inshore nursery areas (Holland and Yelverton 1973). In 1978, the majority of alewives collected offshore were juveniles and yearlings. Most (78.8%) of the alewives collected were distributed from 18.4 km NNE of Cape Hatteras Lighthouse to the Chesapeake Bay Entrance. The largest single catch occurred 35.2 km east of Chesapeake Light Tower (Lat. 36° 54'N) during February. Most (78.3%) were caught at depths ranging from 19.8 to 36.0 m (Johnson et al. 1978).

LAKE MATTAMUSKEET - Juveniles 24 to 105 mm long were captured in the lake in January as well as June and November, even though free access to the marine environment was maintained (Tyus 1972).

NORTHEAST CAPE FEAR RIVER - Young alewife were found throughout the river system, with greatest abundance in the lower river and in tributaries (Table 3.9-2). Seaward migration occurred in November 1976 (Sholar 1977b).

Cooper (1961) and Kissil (1969) reported that juvenile migration occurred only during daylight hours and that the major stimulus to leave was increased water flow. Fish size did not play a role in time of departure from Bride Lake, Connecticut (Kissil 1969).

3.9.8.2 Adult Migration and Local Movement

Migration and movement of alewives in Northeast rivers has been studied in detail. Movements have been correlated with fluctuating environmental variables. Activity patterns of alewife in Southeast waters is difficult to study due to the presence of blueback herring.

In Connecticut, adults enter freshwater in waves controlled by water temperature and spend several days to two weeks on the spawning grounds. The amount of time spent on the spawning grounds varies so that the spent population returning to sea encounters the upcoming unspawned fish in the stream (Cooper 1961). The rate of upstream movement is correlated with increasing water temperature (Cooper 1961). Temperature probably initiates and terminates the seasonal freshwater migration (Kissil 1969).

Migratory activity is harmonic with a diurnal periodicity and is closely associated with incident solar radiation (Saila et al. 1972). Light intensity

Table 3.9-2. Nursery areas of juvenile alewife.

RIVER SYSTEM	LOCATION	SOURCE(S)
Neuse River	Summer: Beard Creek; November through March: lower Neuse and western and northern Pamlico Sound	Spitsbergen and Wolff (1974) Marshall (1976, 1977)
	Duck Creek	[illegible] (1979)
New River	Lower channelized section during October 1973	Sholar (1975)
White Oak River	Primary: Hunter Creek, [illegible], [illegible] and [illegible] Creeks	Sholar (1975)
Northeast Cape Fear River	Mouth to NC Hwy 53 including tributaries. Major concentration in lower river and tributaries	Sholar (1977)
Cape Fear River	Downstream from Wilmington to upstream from I 95 near Fayetteville (RM 111)	Fischer (1980)

and stream temperature determined timing of entry into freshwater (Bride Brook, Connecticut) from Long Island Sound; low light intensity was required (Kissil 1969). Adult alewife entered Bride Brook only after sunset throughout the migration.

Adults moved voluntarily through the fish ladder on overcast days but would move up through the ladder on sunny days only when they were heavily concentrated in the stream (Kissil 1969). Daily numbers migrating were not correlated with water temperature, moonlight, or tidal conditions (Kissil 1969).

Adult migrators blocked by a dead-end fork of a stream immediately returned to the ocean unspawned (Cooper 1961).

Subadults are present in the Connecticut River at the same time as adults but remain in the lower section (Kissil 1969).

Alewife placed in the tailrace of a hydroelectric power plant on the Gaspereau River, Nova Scotia, took six to seven days to move into the fishway adjacent to the power plant. The rate of fish movement from pool to pool within the fishway was faster than the rate at the entrance. Crowding tests showed that the exit rate from fishway pools increased slightly curvilinearly with higher fish densities. Fishway capacity was estimated at 2000 fish per hour. Fish stopped to recover from fatigue in the two larger "rest pools" (Dominy 1971).

In North Carolina, adults frequent offshore areas during the latter half of February and March before the spawning migration (Holland and Yelverton 1973). Greastest abundance of alewife in Albemarle Sound apparently occurs in the Chowan River; 85% of alewife landed in the Sound came from the river (Loesch et al. 1977, Johnson et al. 1978). Peak abundance of alewife in the New River occurs in January and February, with most occurring in Blue and Hawkin's Creeks (Sholar 1975).

Adult alewife did not enter the White Oak River until March or April 1974, a phenomenon which disagrees with the sequence of events elsewhere. In 1974, adults were found up to the Quarry Lakes in April and May, but none were found in tributaries. The 1975 run was much larger; alewife were caught from February through May

upstream to the Quarry Lakes and were also found in Hunter, Grant, and Holston Creeks. Grant Creek was the site of greatest abundance (Sholar 1975).

Adult alewife first entered the Northeast Cape Fear River during February 1976 and remained until April. Gill nets caught them upstream as far as Pik Creek and were caught in only one other tributary - Prince George Creek. Alewife probably used other lower tributaries but were not located. Catches indicated that alewife migrated earlier but were not distributed upstream as far as blueback herring (Sholar 1977b).

3.9.8.3 Responses to Stimuli

TEMPERATURE - Adult alewife prefer warmer water with low free carbon dioxide content (Collins 1952). Temperature probably initiates and terminates the seasonal freshwater migration (Kissil 1969). The rate of movement into freshwater areas of Parker River, Massachusetts, was governed by water temperature and modified by tide stage and river discharge (Libey 1976).

LIGHT - Light intensity determines the time of entry into freshwater and subsequent movement upstream over a 24-hour period (Kissil 1969). Positive phototropic reponses were noted for alewife except during the spawning period in Cayuga Lake, New York (Rothschild 1966). Seaward migration of juveniles occurs only during daylight hours (Cooper 1961).

WATER FLOW - Water velocity and turbulence, along with visual stimuli, can influence orientation (Collins 1952).

3.9.9 Population

3.9.9.1 Sex Ratio

CHOWAN-SCUPPERNONG RIVERS - Males outnumbered females 1.6:1 in 1975 (Holland et al. 1975), 1.14:1 in 1977 (Loesch et al. 1977), and [illegible] in 1978 (Johnson et al. 1978).

WHITE OAK RIVER - Male to female ratio was 1.5:1 in 1975 (Sholar 1975).

NORTHEAST CAPE FEAR RIVER - Males outnumbered females 2.2:1 in 1976 (Sholar 1977b).

CAPE FEAR RIVER - Females dominated males 1:3 in 1978 (Fischer 1980).

3.9.9.2 Age Composition

Alewife populations in North Carolina are comprised mainly of age IV and V adults (Table 3.9-3).

3.9.9.3 Size Composition

Female alewife are larger than males of similar age (Table 3.9-4).

3.9.9.4 Abundance and Population Status

Alewife populations in North Carolina have been in decline since the late 1960s mainly due to overfishing in offshore waters by foreign countries (McCoy 1976). In Albemarle Sound, alewife comprised only four percent of the river herring population in 1977 (Loesch et al. 1977) and 19% in 1978 (Johnson et al. 1978). Refer to Section 3.8 "Blueback Herring" for a summary of the overfishing problem.

The status of alewife populations in river systems within Region 4 was estimated from responses to the questionnaire returned by various State and Federal agencies (Section 4). Most alewife populations in North Carolina appear to be declining, and several may be threatened (Table 3.9-5). The status of alewife populations in South Carolina and Georgia are not known. Factors possibly contributing to their decline are presented in Table 3.9-6.

3.9.9.5 Factors Affecting Reproduction and Recruitment

A study by Havey (1973) determined a significant linear relationship between the number of juvenile emigrants and the number of adult immigrants four years later to Love Lake, Washington County, Maine. In addition, there was a significant linear relationship between the log of magnitude of female escapement and the log of the number of juvenile emigrants produced (Havey 1973). Recruitment rates of alewife in the Parker River, Massachusetts, varied with sex and age (Libey 1976). For every female which entered Bride Lake, Connecticut, 2.88 fry left and returned to sea (Kissil 1969). Recruitment to the spawning population in Albemarle Sound occurs predominantly at ages IV and V (Pate 1974). The interactions among mortality rates

and variable recruitment rates was proposed by Libey (1976) as the source of a four-to five-year cyclical perpetuation of a year class character (strong or weak) noted by other investigators.

3.9.9.6 Mortality

EGGS - The freshwater mortality for alewife eggs in Bride Lake was estimated as 99.998% - one egg in 80,000 survived and developed to the point where the young fish migrated to sea (Kissil 1974).

ADULTS - Alewife exhibit considerable mortality in freshwater (Cooper 1961); adult mortality on the spawning grounds in Bride Lake, Connecticut, was 57.44% in 1966 and 48.60% in 1967 (Kissil 1969). The rate for fish participating in the Parker River, Massachusetts, spawning migration varied from 40% (1972-73) to 48.5% (1974-75) while the mortality rate for unspawned fish was constant (42%)(Libey 1976). High adult mortality may be due to the inability of alewife to quickly acclimate to fluctuating temperatures or to the persistence of an upper lethal temperature; osmoregulatory stress and large energy expenditures may weaken fish and contribute to mortality (Cooper 1961). Rothschild (1966) reported, however, that mass mortality of alewives in Cayuga Lake, New York, was caused by variables other than temperature. Serum and tissue samples collected from adult alewives caught in Lake Michigan revealed transient hyponatremia in June and July, with an increased sodium content of the tissues and no change in potassium levels (Stanley 1969). Calcium levels changed during the breeding season, which suggested deposition of calcium in bone but not in scales (females did not show hypercalcemia during breeding season). The shifts between body fluid compartments may be a contributing factor in mass mortalities observed for alewife (Stanley 1969). Mortality of alewife in Albemarle Sound was estimated as 72% in 1977 (Loesch et al. 1977) and 42% in 1978 (Johnson et al. 1978).

3.9.10 Predator-Prey Relationships

EGGS - Yellow and white perches consume newly-hatched eggs (Kissil 1969). Vertebrates and invertebrates consume alewife eggs, but there was no evidence of the level of consumption (Cooper 1961). Larger spottail shiners and alewives feed lightly on alewife eggs but small spottail and alewife appear to be effective alewife egg consumers (Edsall 1964).

Table 3.9-3. Age composition (%) of alewife populations in river systems within Region 4. M = males; F = females; C = sexes combined.

RIVER SYSTEM AND YEAR	SEX	I	II	III	IV	V	VI	VII	VIII	IX	SOURCE(S)
Offshore North Carolina											
1971	C				16	28	32	20	4		Holland and Yelverton (1973)
Albemarle Sound	M		< 1	15	47	30	7	< 1	0	0	Holland et al. (1975)
1975	F		0	2	47	31	16	3	< 1	< 1	
1977	M			1	44	49	7	< 1	0		Loesch et al. (1977)
	F			< 1	28	63	6	2	< 1		
1978	M			5	66	23	6	< 1	–		Johnson et al. (1978)
	F			3	56	32	6	2	< 1		
Chowan River	M			3	37	45	7	5	3		Holland and Yelverton (1973)
1971	F			0	27	27	27	8	12		
1975	M		2	9	42	34	11	< 1			Holland et al. (1975)
	F		0	0	50	28	17	5			
1977	M			3	49	42	4	1	0		Loesch et al. (1977)
	F			0	25	67	4	0	4		
1978	M			7	78	12	3	0			Johnson et al. (1978)
	F			5	63	23	7	2			
Edenton Bay	M					7	40	38	14	0	Holland et al. (1975)
1975	F					0	13	50	13	25	
Scuppernong River	M			27	43	25	5	0			Holland et al. (1975)
1975	F			7	43	35	14	1			

Table 3.9-3. Age Composition (cont'd.).

RIVER SYSTEM AND YEAR	SEX	I	II	III	IV	V	VI	VII	VIII	IX	SOURCE(S)
1977	M				25	73	2				Loesch et al. (1977)
	F				21	76	2				
1978	M			12	75	12					Johnson et al. (1978)
	F			43	57	0					
Meherrin River 1975	M				33	33	33	0	0	0	Holland et al. (1975)
	F				13	37	25	6	13	6	
1977	M			2	59	35	5	0			Loesch et al. (1977)
	F			<1	30	61	7	2			
1978	M			5	63	27	6	0	0		Johnson et al. (1978)
	F			2	63	28	5	0	2		
[illegible] River 1975	M			[illegible]	64	40	1				Holland et al. (1975)
	F			0	60	28	11				
1977	M				39	52	10	0	0		Loesch et al. (1977)
	F				30	56	8	5	1		
1978	M			3	55	31	9	<1			Johnson et al. (1978)
	F			1	50	43	7	5			
Perquimans River 1975	M			5	57	37	4	3			Holland et al. (1975)
	F			0	38	45	14	8			
Yeopim River 1975	M				63	36	1	0			Holland et al. (1975)
	F				0	50	0	50			

Table 3.9-3. Age Composition (cont'd.).

RIVER SYSTEM AND YEAR	SEX	AGE CLASS I	II	III	IV	V	VI	VII	VIII	IX	SOURCE(S)
Neuse River	M			10	41	33	13	4	0		Marshall (1977)
1977	F			0	8	18	47	20	6		
New River	M				-	100					Sholar (1975)
1974-75	F				33	67					
White Oak River	M			8	72	20					Sholar (1975)
1974-75	F			0	76	24					
Northeast Cape Fear River											
1976	M			8	84	3	5				Sholar (197[illegible]b)
	F			0	58	35	6				

Table 3.9-4. Size composition (mean fork length in mm) of alewife populations in river systems within Region 4. M = males; F = females; C = sexes combined.

RIVER SYSTEM AND YEAR	SEX	I	II	III	AGE CLASS IV	V	VI	VII	VIII	IX	SOURCE(S)
Offshore North Carolina 1971	C				245	249	261	270	274		Holland and Yelverton (1973)
Chowan River 1971	M			221	231	242	256	249	266		Holland and Yelverton (1973)
	F			-	245	246	262	269	284		
Neuse River 1973	M			[illegible]	247	257	268	278	-		Marshall (1977)
	F			-	256	265	274	286	289		
New River 1976-77	M				-	266					Sholar (1978)
	F				[illegible]	289					
White Oak River 1976-77	M			231	241	250					Sholar ([illegible])
	F			-	256	272					
Northeast Cape Fear River 1976	M			[illegible]	239	240	261				Sholar (1977b)
	F			-	[illegible]	257	275				

Table 3.9-5. Status of alewife, Alosa pseudoharengus, in river systems within Region 4 based on questionnaire responses to question VI-2. S = response from marine representative; F = response from freshwater representative; C = response from other agencies.

RIVER SYSTEM	STATUS
NORTH CAROLINA	
Currituck Sound	Declining (S)
Albemarle Sound	Declining (SF)
North R.	Declining (S)
Pasquotank R.	Declining (S)
Little R.	Declining (S)
Perquimans R.	Declining (S)
Yeopim R.	Declining (S)
Chowan R.	Declining (SF), Threatened (C)
Meherrin R.	Declining (S)
Roanoke R.	Declining (SFC)
Cashie R.	Declining (S)
Scuppernong R.	Declining (S)
Alligator R.	Declining (S)
Pungo R.	Not known (S)
Pamlico R.	Not known (S)
Tar R.	Stable (S) or Declining (SFC)
Neuse R.	Stable (S) or Declining (SFC)
Trent R.	Stable or declining (SC)
North R.	Not known (S)
Newport R.	Not known (S)
White Oak R.	Declining (C)
New R.	Threatened (S)
Cape Fear R.	Stable (S) or Declining (SFC)
Northeast Cape Fear R.	Stable (S) or Declining (SFC)
Black R.	Not known (S)
Pee Dee R.	Declining (F)
SOUTH CAROLINA	
Waccamaw R.	Not known (S)
Pee Dee R.	Not known (S)
Black R.	Not known (S)
Sampit R.	Not known (S)
Santee R.	Not known (S)
Cooper R.	Not known (S)
Ashley R.	Not known (S)
Edisto R.	Not known (S)
Ashepoo R.	Not known (S)
Combahee R.	Not known (S)
Savannah R.	Not known (S)

Table 3.9-6. Factors possibly important or very important in contributing to the decline of certain populations of alewife, *Alosa pseudoharengus*, within Region 4 based on questionnaire responses to question I. S = response from marine representative; F = response from freshwater representative: C = response from other agencies.

NORTH CAROLINA

- Channelization (FC)
- Dredge and fill projects (F)
- Dams and impoundments (FC)
- Industrial water intakes (FC)
- Location of industrial discharges (FC)
- Chemical pollution (F)
- Turbidity (F)
- Low oxygen levels (FS)
- Inadequate fishway facilities (F)
- Inadequate control of water release from dams (C)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)
- Poor food availability (F)
- Sewerage outfalls (C)
- Spawning areas too accessible to fishermen (C)
- Poor water quality (FSC)

SOUTH CAROLINA

- Inadequate information

GEORGIA

- Inadequate information

JUVENILES - Predators of juvenile alewife include American eel and white perch (Kissil 1969), grass pickerel, largemouth bass, yellow perch, and pumpkinseed (Cooper 1961).

ADULTS - Predators of adults include fish hawks, green herons, mink (Cooper 1961), and lake trout (Salvelinium namaycush) (Gudger 1929, Royce 1943).

3.9.11 Diseases

No information available.

3.9.12 Exploitation

3.9.12.1 Gear

NORTH CAROLINA - Alewife are captured by anchor gill nets, drift gill nets (Roanoke River only), haul seines, and pound nets (Pate 1974).

3.9.12.2 Fishing Areas

Fishing for alewife in North Carolina occurs in those areas reported for blueback herring (Section 3.8.12.2).

3.9.12.3 Fishing Seasons

Seasons are similar to those reported for blueback herring (Section 3.8.12.3).

3.9.12.4 Effort

No direct information available. Refer to Section 3.8.12.4

3.9.13 Protection and Management

Refer to Section 3.8.13.1 for a review of North Carolina's policy regarding protection and management of river herring.

3.9.13.1 Marking

Bismark brown Y was found to be more suitable than neutral red for immersion staining of young alewives. It is less toxic than neutral red and produces an identifiable mark for a longer time; it may be of practical use in population estimates if handling mortality can be reduced (Jessop 1973). Fins may be less desirable than the operculum as sites of attachment for the placement of tags on alewives (Dominy and Myatt

1973). Muscle myogen and LDH (Lactate dehydrogenase) electrophoretic patterns are of little use as biochemical population markers for alewife (McKenzie 1973).

3.9.13.2 Transport

Alewives transported for transplant showed greater mortality in females than in males. This aspect, coupled with the variation in the natural sex ratio, makes it advisable to sex fish during transplant operations (Brown 1969).

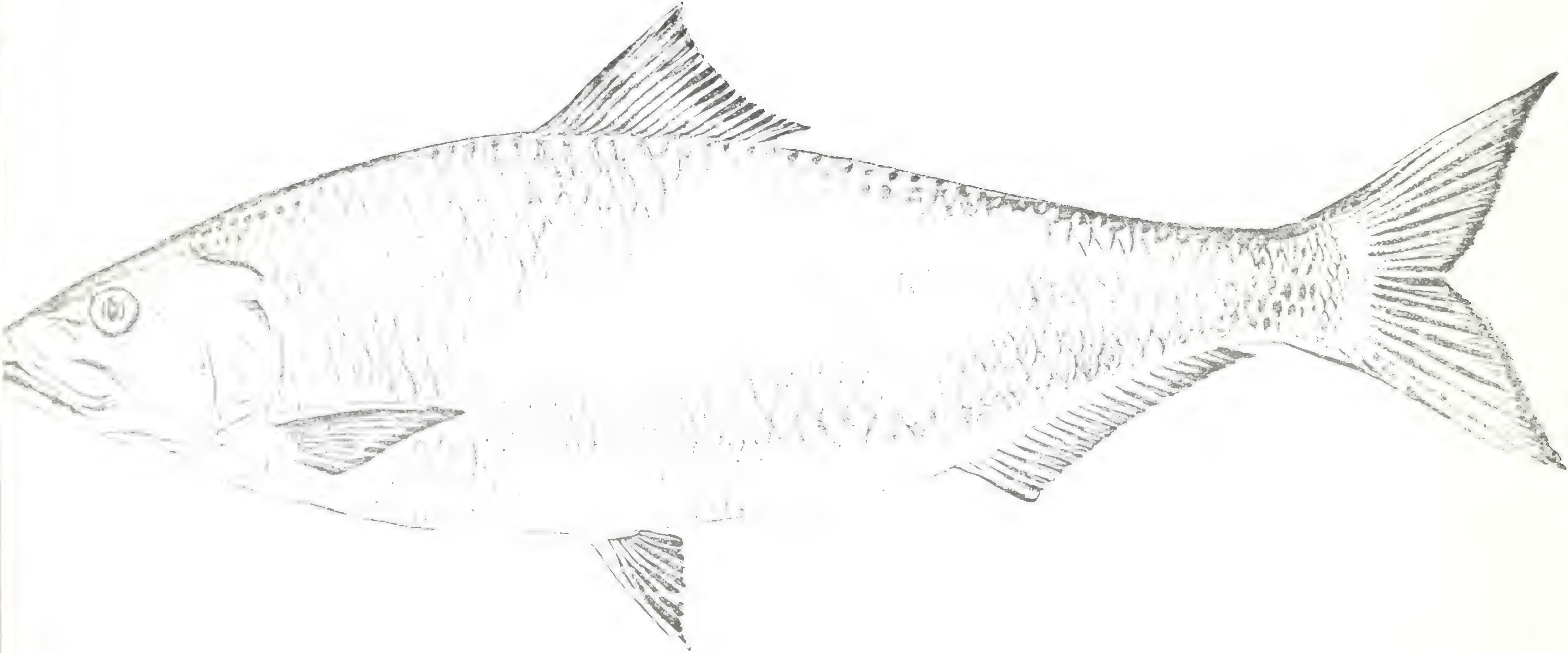
3.9.13.3 Fishways

A study by Dominy (1971) examined utilization of fishways by alewife. A pool and weir fishway on the Gaspereau River, Nova Scotia, was built at an elevation 0.21 m (eight inches) lower than the existing conventional weir and passed alewives at a significantly greater mean rate (56.25 min^{-1}) than the conventional weir (37.59 min^{-1}). Mean rate of passage from pool to pool was not significantly different. Alewife do not require any more time per fishing pool than Pacific salmon. Demand of alewife on water volume is six times less than that required for Pacific salmon. Maximum use of the fishway requires stable water levels in the tailrace at the fishway entrance, and the entrance is better located near an area of relatively quiet water rather than fast-moving, turbulent water (Dominy 1971).

Fishway utilization by alewife in the Annaquatucket River, Rhode Island, has been monitored by an automatic recording system for counting and measuring water temperature, dissolved oxygen, pH, and solar radiation (Saila et al. 1972).

3.9.13.4 Locking

Spawning runs of alewife and blueback herring have declined in previous years in the Cape Fear River estuary due to the installation of several locks upstream from Wilmington, North Carolina. These runs are being rehabilitated by locking adult migrants to upriver spawning sites (W.D. Baker and H.W. Street 1981, pers. comm.).



Alabama shad

Alosa alabamae

3.10 Alabama Shad (*Alosa alabamae*)

3.10.1 Historical Significance

The Alabama shad is a little-studied anadromous clupeid, which migrates into rivers draining the upper Florida peninsula along the Gulf of Mexico to the Mississippi River drainage (Williams and Grey 1975). Alabama shad forms a geographically disjunct species pair with American shad, *Alosa sapidissima* (Berry 1964). The morphological and meristic characters closely resemble those of American shad, but Alabama shad was described as being a separate species by Jordan and Evermann in 1896.

Alabama shad is the most prevalent anadromous species on the Florida west coast with its center of abundance in the Apalachicola River (Laurence and Yerger 1967). Populations of shad are small, and coastal distribution has been limited perhaps by increased siltation and the presence of locks and impoundments (Lee et al. 1980).

Athough Alabama shad is not presently exploited as a food fish, its flesh, though not as tasty as American shad, is edible. In some areas, sport fishermen prize the adults for their roe (Williams and Grey 1975). Populations in rivers of northwest Florida have a good potential for a sport fishery during spawning run (Mills 1972), but there is no indication that a significant fishery will ever develop due to lack of interest by fishermen (Williams and Grey 1975).

3.10.2 Distribution

3.10.2.1 Range

The historical range of Alabama shad is from the Suwannee River, Florida, west to the Mississippi River (Williams and Grey 1975). Alabama shad do not regularly migrate into any Gulf coast rivers south of the Suwannee River (Williams and Grey 1975).

3.10.2.2 Eggs

During April 1971 shad eggs were collected in the main channel of the Apalachicola River over a coarse sand and gravel bottom (Mills 1972).

3.10.2.3 Larvae

During April 1971 shad larvae were collected only at night in the main channel of the Apalachicola River in areas with appreciable water current (Mills 1972).

3.10.2.4 Juveniles

Juveniles were never collected in areas of still or back water of the Apalachicola River; they migrated downstream and entered saltwater at 120 mm fork length or at smaller sizes in cold weather (Mills 1972).

3.10.2.5 Adults

Alabama sahd enter the Apalachicola River in late winter to early spring, spawn rather abruptly, and immediately die or leave the area (Laurence and Yerger 1967). The majority of the spawning population is assumed to remain in the main river channel. Daily and migratory distributions are not known.

3.10.3 Reproduction

3.10.3.1 Maturity

Maturation occurs at an earlier age and smaller size than for American shad (Laurence and Yerger 1967, Mills 1972). During the 1966 spawning run, some age class I males were in evidence at the end of the season; the age II year class was comprised mostly of males and small numbers of females (Laurence and Yerger 1967). Age class I males and II females were the youngest adults to migrate up the Apalachicola River in 1969 and 1970 (Mills 1972).

3.10.3.2 Mating

No information available.

3.10.3.3 Fertilization

No information available.

3.10.3.4 Fecundity

Apalachicola River shad contained 46,400 to 167,450 eggs in 1966 (Laurence and Yerger 1967), 61,236 to 257,655 eggs in 1969, and 108,864 to 271,207 eggs in 1970 (Mills 1972).

3.10.4 Spawning

3.10.4.1 Season and Location

Apalachicola River - Adults enter the river as early as January or as late as March and spawn in April (Mills 1972). Laurence and Yerger (1967) reported gradual ripening of gonads with increasing temperature during

their stay in the river. However, Mills (1972) reported that gonads of shad entering the river were in ripe condition. Hypothesized areas of spawning in 1969 and 1970 were the Chipola River, Chattahoochee-Flint River (above Jim Woodruff Dam), and the area immediately below the dam (Mills 1972).

3.10.4.2 Temperature

Apalachicola River shad spawned at 20 C in 1966 (Laurence and Yerger 1967), 19 to 22 C in 1969-70, and 19 to 23 C in 1971 (Mills 1972).

3.10.4.3 Spawning Habitat

Alabama shad in the Apalachicola River spawned over coarse sand and gravel with a moderate current of 0.5 to 1.0 m s^{-1} (Laurence and Yerger 1967, Mills 1972).

3.10.4.4 Diel Spawning Patterns

No eggs were collected in the Apalachicola River during daylight in 1969 and 1970 (Mills 1972).

3.10.5 Life History - Eggs and Larvae

3.10.5.1 Hatching and Growth

No information available.

3.10.5.2 Hardiness

No information available.

3.10.5.3 Swimming Ability

No information available.

3.10.5.4 Chemical Tolerances

No information available.

3.10.5.5 Pressure

No information available.

3.10.6 Life History - Juveniles

3.10.6.1 [illegible]

FEEDING - Juveniles in the Apalachicola River feed largely on small [illegible] in the

Woodruff Dam area contained greater mean volume of food per stomach than downriver fish; Woodruff Dam fish fed on a more varied diet including small clupeid fishes, which may have contributed to the fast growth of juveniles in the Woodruff Dam region (Laurence and Yerger 1967).

GROWTH - Growth of most juveniles in the Apalachicola River is 30 mm per month (Mills 1972). Length frequency data for 1970 indicated three separate spawning populations between July and November. The first group was spawned below Woodruff Dam (RM 102-107) and appeared in July at a modal fork length of 75 mm; by August this mode had reached 105 mm. The second group appeared at a mode of 65 mm FL in August and reached 95 mm in September; these fish were probably spawned in the Chipola River north of Marianna, Florida, in late April or May. The third group appeared in September with a mode of 55 mm increasing to 65 mm in October and 75 mm by November; this group was probably spawned above Jim Woodruff Dam from adults which gained access to the Chattahoochee-Flint Rivers through navigation locks. Juveniles over 125 mm FL were not collected in the river, suggesting emigration to saltwater independent of temperature (Mills 1972).

METABOLISM - No information available.

3.10.6.2 Hardiness

No information was available concerning the hardiness of juvenile Alabama shad to salinity-temperature interaction, acclimation, oxygen, suspended sediments, pH, and transport.

SALINITY - Juveniles enter saltwater at 120 mm FL or at smaller sizes in cold weather (Mills 1972).

TEMPERATURE - Waters below Woodruff Dam ranged from 11.6 to 31.0 C during 1969-70; some of the juveniles spawned above the dam must have passed through the area during summertime elevated temperatures on their seaward journey (Mills 1972). Tolerances were not reported.

3.10.6.3 Swimming Ability

No information available.

3.10.6.4 Chemical Tolerances

No information available.

3.10.6.5 Pressure

No information available.

3.10.7 Life History - Adults

3.10.7.1 Longevity

Apalachicola River - Small numbers of age IV shad were collected in 1966; most were females (Laurence and Yerger 1967). Age III males and females were the oldest adults present in 1969 and 1970 (Mills 1972).

3.10.7.2 Nutrition and Growth

FEEDING - Adults take little or no food during the spring migration but can be lured and caught on unbaited silver hooks (Laurence and Yerger 1967). Juvenile centrarchids were found in 0.8% of the stomachs examined by Mills (1972).

GROWTH - Females were longer and heavier than males in every age class; the length-weight relationship for adults in the Apalachicola River was described by the equation

$$\text{Log } W = -2.8312 + 3.5657 \text{ Log } L,$$

where W is weight in pounds and ounces and length is expressed in inches (Laurence and Yerger 1967).

METABOLISM - No information available.

3.10.7.3 Hardiness

Little is known about the hardiness of adult Alabama shad to salinity, salinity-temperature interactions, acclimation, oxygen, suspended sediments, pH, and transport.

TEMPERATURE - Data from Laurence and Yerger (1967) indicated that adults first entered the Apalachicola River as water temperatures reached 15 C and were absent at temperatures above 23 C. Data from Mills (1972) indicated declines in catches during periods when temperatures dipped to 12.1 C.

3.10.7.4 Swimming Ability

No information available.

3.10.7.5 Chemic[illegible]

No information available.

3.10.7.6 Pressure

No information available.

3.10.8 Behavior

3.10.8.1 Juvenile Migration and Location Movement

Three distinct size groups were found in the Apalachicola River between July and November by Mills (1972). Localized distributions and habitats were not reported. Approximate times of emigration were as follows:

GROUP 1 - Spawned in the area of Jim Woodruff Dam, some emigration by August.

GROUP 2 - Spawned in the Chipola River, nearly all absent by October.

GROUP 3 - Spawned above Jim Woodruff Dam, emigration sometime after November.

Similar results were reported by Laurence and Yerger (1967).

3.10.8.2 Adult Migration and Local Movement

Adult shad enter the Apalachicola River as early as January and as late as March, and attain peak numbers in April. Males outnumber the females at temperatures lower than 17 C. Adults spawn at 20 C and then immediately die or leave the area. Turbidity and water turbulence prevent adequate observation for mortality. Migration patterns and habitats sought by adults in the Gulf of Mexico are not known.

3.10.8.3 Responses to Stimuli

LIGHT - The inability of Mills (1972) to collect eggs and larvae during daylight sampling suggests that spawning may occur only in darkness.

TEMPERATURE - Water temperature appears to play a major role in the migration and spawning activity of Alabama shad. Shad entered the river when temperatures reached 15 C; catches declined when temperatures dipped in March. Gradual ripening of the gonads was observed with increasing water temperature until 20 C in late April, at which time spawning occurred abruptly (Laurence and Yerger 1967).

3.10.9 Population

3.10.9.1 Sex Ratio

Data from Mills (1972) indicates males arrive first and remain dominant over females throughout the spawning season. In 1969, the male to female ratio was 1.39:1; in 1970 males outnumbered females by 2:1. The majority of males enter the river at temperatures less than 17 C; above 17 C females outnumber males in collections (Mills 1972).

3.10.9.2 Age Composition

Age classes that comprised the 1966 spawning run of Alabama shad in the Apalachicola River were presented by Laurence and Yerger (1967):

SEX	AGE CLASS (%)			
	I	II	III	IV
Male	5.7	34.3	50.0	10.0
Female	–	11.3	69.0	19.7

The 1969-70 spawning population was comprised mainly of age class II and III shad, although some age II fish had previous spawning marks on their scales (Mills 1972).

A marked decrease in the mean age of males occurred during the latter portion of the spawning run in 1969-70 (Mills 1972). This decrease was attributed to a large number of yearling males that entered the spawning population. Mills (1972) interpreted this as an adaptive measure to maintain high quality and quantity of spermatoza for late-spawning females.

3.10.9.3 Size Composition

Females were consistently larger then males of similar age (Table 3.10-1).

3.10.9.4 Abundance and Population Status

A commercial fishery for Alabama shad does not exist in Florida even though the population appears large enough to support one. Sportfishermen catch Alabama shad incidentally while fishing for other game fish, and are used as live bait for striped bass (Mills 1972).

Table 3.10-1 Size composition (mm) of Alabama shad populations in river systems within Region 4. M = males; F = females; TL = total length; FL = fork length.

RIVER SYSTEM AND YEAR	SEX		AGE CLASS I	II	III	IV	SOURCE(S)
Alapachicola River							Laurence and Yerger (1967)
1967	M	(TL)	269	340	366	384	
	F	(TL)	-	368	389	409	
1968	M	(FL)	255	316	334		Mills (1972)
	F	(FL)	-	340	356		
1969	M	(FL)	219	326	-		Mills (1972)
	F	(FL)	-	346	376		

The status of Alabama shad in Gulf coast waters was estimated from responses to the questionaire returned by State agencies (Section 4). Disagreement was common when two respondees estimated shad status for one river system. The general consensus, however, was that status of Alabama shad in Gulf coast waters is not known or appears to be in decline (Table 3.10-2). Factors possibly contributing to the decline of Alabama shad populations are listed in Table 3.10-3.

3.10.9.5 Factors Affecting Reproduction and Recruitment

No information available.

3.10.9.6 Mortality

No information available.

3.10.10 Predator-Prey Relationships

No information available.

3.10.11 Diseases

No information available.

3.10.12 Exploitation

3.10.12.1 Gear

Staked gill nets, drift gill nets, dip nets, and rod and reel are used to capture Alabama shad in the Apalachicola River.

3.10.12.2 Fishing Areas

No information available.

3.10.12.3 Seas

No information available.

3.10.12.4 Effort

The sportfishing potential for Alabama shad in the Apalachicola River is excellent with an average of one fish caught every 29.72 minutes per rod used (Mills 1972). The U.S. Fish Commission reported commercial landings of Alabama shad of 6977 pounds in 1889 and 105 pounds in 1902. No commercial landings have been re

Table 3.10-2. Status of Alabama shad, *Alosa alabamae*, in river systems within Region 4 based on questionnaire responses to question VI-2. S = response from marine representative, F = response from freshwater representative.

RIVER SYSTEM	STATUS
FLORIDA (Gulf coast)	
Hillsborough R.	Probably never present (S)
Suwannee R.	Probably never present (S)
Apalachicola R.	Declining (S), Stable (F)
Ocklockonee R.	Probably never present (F)
Escambia R.	
ALABAMA	
Alabama R.	Declining (S), Stable (F)
Tombigbee R.	Declining (S), Stable (F)
Perdido R.	Not known (S)
Bon Secour R.	Not known (S)
Fish R.	Not known (S)
Magnolia R.	Not known (S)
Dog R.	Not known (S)
Fowl R.	Not known (S)
Tennessee R.	Stable (F)
Chattahoochee R.	Stable (F)
Coosa R.	Declining (F)
Tallapoosa R.	Declining (F)
MISSISSIPPI	
Pascagoula R.	
Tchouticabouffa R.	
Biloxi R.	
Wolf R.	
Jourdan R.	
Pearl R.	
LOUISIANA	
Pearl R.	Not known
Bayou LaCombe	Not known
Tchefuncte R.	Not known
Tangipahoa R.	Not known
Tickfaw R.	Not known
Amite R.	Not known
Mississippi R.	Not known
Atchafalaya R.	Not known
Vermillion R.	Not known
Mermentau R.	Not known
Calcasieu R.	Not known
Sabine R.	Not known

Table 3.10-3. Factors possibly important or very important in contributing to the decline of certain populations of Alabama shad, *Alosa alabamae*, within Region 4 based on questionnaire responses to question I. S = response from marine representative; F = response from freshwater representative.

FLORIDA

- Channelization (S)
- Dams and impoundments (S)
- Reduction in spawning habitats (S)

GEORGIA

- Dams and impoundments (F)
- Inadequate fishway facilities (F)

ALABAMA

- Bulkheading (F)
- Dams and impoundments (FS)
- Location of industrial discharges (FS)
- Road construction (S)
- Low oxygen levels (S)
- Sewerage outfalls (S)
- Inadequate fishway facilities (FS)
- Inadequate control of water release from dams (F)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)
- Poor food availability (S)
- Poor water quality (FS)

MISSISSIPPI

- Inadequate information

LOUISIANA

- Inadequate information

3.10.13 Protection and Management

3.10.13.1 Florida

An anadromous survey conducted by Williams and Grey (1975) found that populations of Alabama shad were small and occurred only in rivers north of the Suwannee River, indicating that they have reached the southern limit of their range due to thermal regime or lack of suitable spawning and nursery areas. These populations are not extensively exploited or immediately threatened by environmental alteration. Their study concluded that research on Alabama shad was not desirable at the time.

3.10.13.2 Alabama

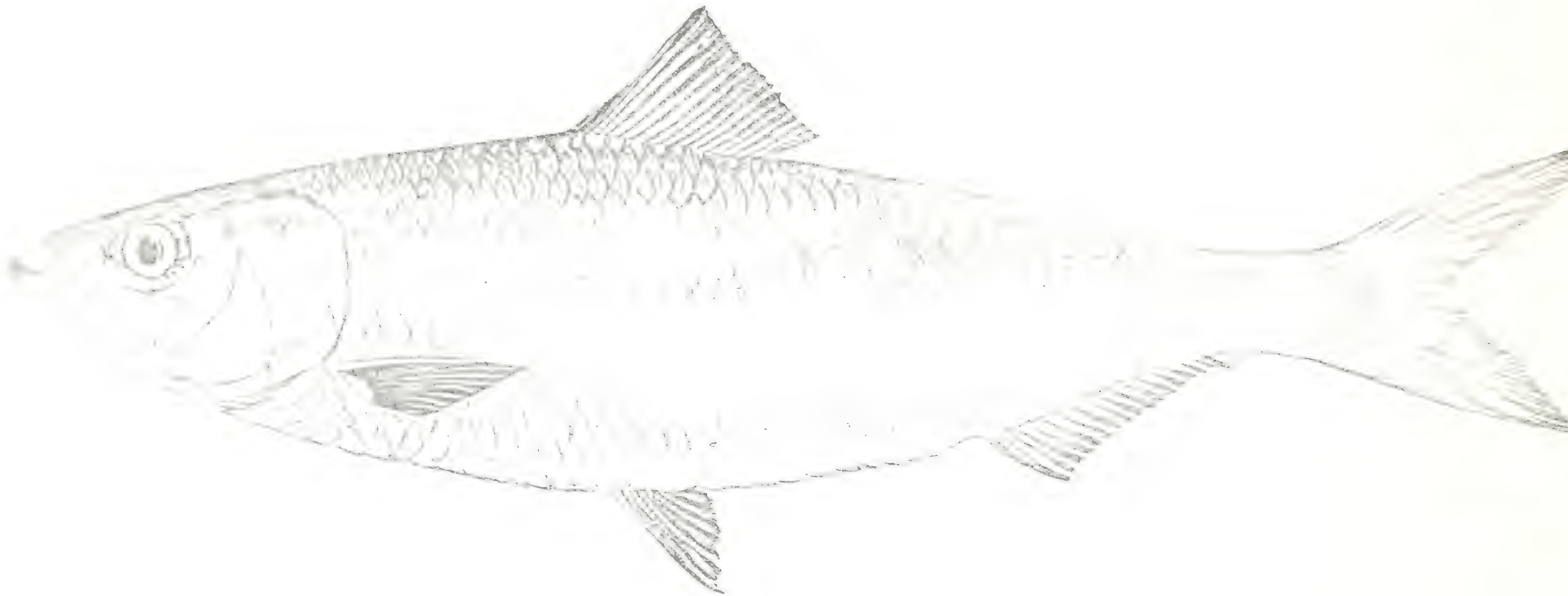
No information available.

3.10.13.3 Mississippi

No information available.

3.10.13.4 Louisiana

No information available.



Skipjack herring

Alosa chrysochloris

3.11 Skipjack Herring (*Alosa chrysochloris*)

Little information has been published concerning the skipjack herring. The following account was taken from a compilation of information by G.H. Burgess (Lee et al. 1980): "Skipjack herring is a highly migratory, peripheral freshwater species which ranges from Florida to Texas. In freshwater it is found from the Apalachicola River west to the Colorado River. Skipjack is also common in the Mississippi River and its larger tributaries, but has been extirpated from the upper Mississippi system following construction of navigational facilities. Skipjack herring prefers clear, deep waters and has been found in increasing numbers in the Missouri River after dredging and impoundments have deepened channels and reduced suspended solids."

The status of skipjack herring in Gulf coast waters was estimated from State responses to the questionnaire (Section 4). Most responses indicated the status of skipjack herring is stable in this area (Table 3.11-1). Factors affecting its status are presented in Table 3.11-2.

Table 3.11-1. Status of skipjack herring, *Alosa chrysochloris*, in river systems within Region 4 based on questionnaire responses to question VI-2. S = response from marine representative; F = response from freshwater representative

RIVER SYSTEM	STATUS
FLORIDA (Gulf coast)	
Hillsborough R.	
Suwannee R.	
Apalachicola R.	
Ocklockonee R.	
Escambia R.	
GEORGIA	
Savannah R.	Not known (S), Probably never present (F)
Ogeechee R.	Not known (S), Probably never present (F)
Altamaha R.	Not known (S), Probably never present (F)
Satilla R.	Not known (S), Probably never present (F)
St. Marys R.	Not known (S), Probably never present (F)
Chattahoochee R.	Stable (F)
Flint R.	Stable (F)
ALABAMA	
Alabama R.	Not known (S), Stable (F)
Tombigbee R.	Not known (S), Stable (F)
Perdido R.	Not known (S)
Bon Secour R.	Not known (S)
Fish R.	Not known (S)
Magnolia R.	Not known (S)
Dog R.	Not known (S)
Fowl R.	Not known (S)
Tennessee R.	
Chattachoochee R.	Stable (F)
Coosa R.	Declining (F)
Tallapoosa R.	Declining (F)
MISSISSIPPI	
Pascagoula R.	
Tchouticabouffa R.	
Biloxi R.	
Wolf R.	
Jourdan R.	
Pearl R.	

Table 3.11-1. Skipjack herring (cont'd.).

RIVER SYSTEM	STATUS
LOUISIANA	
Pearl R.	Stable
Bayou LaCombe	Stable
Tchefuncte R.	Stable
Tangipahoa R.	Stable
Tickfaw R.	Stable
Amite R.	Stable
Mississippi R.	Stable
Atchafalaya R.	Stable
Vermillion R.	Stable
Mermentau R.	Stable
Calcasieu R.	Stable
Sabine R.	Stable

Table 3.11-2. Factors possibly important or very important in contributing to the decline of certain populations of skipjack herring, *Alosa chrysochloris*, within Region 4 based on questionnaire responses to question I. S = response from marine representative; F = response from freshwater representative.

FLORIDA

Inadequate information

ALABAMA

Bulkheading (F)
Dams and impoundments (S)
Location of industrial discharges (S)
Road construction (S)
Low oxygen levels (S)
Sewerage outfalls (S)
Inadequate fishway facilities (S)
Inadequate control of water release from dams (F)
Poor food availability (S)
Poor water quality (S)

MISSISSIPPI

Inadequate information

LOUISIANA

Inadequate information

4. QUESTIONNAIRE AND RESULTS

An extensive and detailed questionnaire was sent to officials of Federal agencies and to the major fishery resource agencies (marine and freshwater) of the Southern States. The questions posed referred to species present in State river systems, problems of the fisheries, management programs in operation, and future needs of the States. Although all of the groups responded, many of the replies conflicted and should be resolved before a unified plan for managing these resources is developed.

The results clearly indicated that management efforts now in operation are fragmented, and there is a lack of knowledge available on which to base adequate plans. Further, it illustrated that efforts to protect and restore populations of these fish are poorly coordinated.

4.1 Narrative Analysis

The following section contains results from the questionnaire sent to State and Federal fishery representatives. A copy of the questionnaire is included in Appendix A. The responses were incorporated into the text of this section, which presents the conclusions regarding species present, the extent of commercial and recreational fisheries, stock mitigation and enhancement, the status of stocks, the importance of river systems, and regulations and management within each State. Appendix B contains detailed tables of the respondents. The tables present the answers given by respondents and indicate whether the response was made by a marine, freshwater, or other representative. Tables 4.1-1 through 4.1-44 deal with variables considered to have effects on the status of anadromous fish populations. Examples are channelization (Table 4.1-1) and chemical pollution (Table 4.1-31). The respondents considered each variable and listed the species and river systems that they believed were affected by the variables. Table 4.1-45 is a compilation of questionnaire responses concerning fishery management techniques including regulations, stocking, and others. Table 4.1-46 contains information on the status of anadromous fishes and striped bass x white bass hybrids in river systems. The last table (Table 4.1-47) presents factors considered important or very important that may contribute to the decline of certain populations of anadromous fish stocks.

4.2 Narrative Analysis by State

4.2.1 North Carolina

4.2.1.1 Questionnaire Respondees

Three questionnaires were sent to State and Federal agencies in North Carolina and all were completed and returned. Respondees included: Michael W. Street,

Chief, Fisheries Management Section, North Carolina Department of Natural Resources and Community Development, Division of Marine Fisheries, Morehead City (S); Richard Guier, Fisheries Biologist, North Carolina Wildlife Resources Commission, Route 4 Box 395 - State Fish Hatchery, Fayetteville (F); and Charles S. Manooch, III, Research Biologist, National Marine Fisheries Service, Southeast Fisheries Center, Beaufort Laboratory, Beaufort (C). Following is a summary of the fishery management practices for anadromous stocks in North Carolina based on questionnaire responses from personnel listed above.

4.2.1.2 Overview

Seven anadromous species have (or had) spawning runs in North Carolina waters. These species include Atlantic sturgeon, shortnose sturgeon, striped bass (Atlantic race), American shad, hickory shad, alewife, and blueback herring. All of these species are presently included in a fishery management plan, and all will probably be included in future management plans. At present there is no anadromous species management plan, but there are plans to develop one in the near future for all species listed except for shortnose sturgeon, which is on the State list of endangered species and probably is extinct in North Carolina waters. The North Carolina Division of Marine Fisheries and the North Carolina Wildlife Resources Commission share joint responsibility in managing anadromous fish populations.

4.2.1.3 Commercial Fisheries

All anadromous fish in North Carolina waters, with the exeption of shortnose sturgeon, provide an annual commercial harvest. Only striped bass is presently managed for optimum yield. During spawning season, commercial fishing effort is restricted only for striped bass; fishing is not permitted on spawning grounds during spawning season. Commercial gear types are regulated only for striped bass, and minimum legal size for stripers is 12" TL. There are no quotas on number or weight of anadromous stocks taken by commercial fisheries.

4.2.1.4 Recreational Fisheries

Five anadromous species provide annual sport harvest in North Carolina waters. These species include striped bass, American shad, hickory shad, alewife, and blueback herring. All five species are managed for sport use. There are no restrictions placed upon the recreational fishery regarding fishing effort, location, or gear or

bait types. Creel limits and minimum fish lengths (12" TL) apply only for striped bass.

4.2.1.5 Mitigation - Enhancement

A formal stocking plan is presently in force for striped bass, and State agencies are working to rehabilitate existing runs and restore runs no longer in existence. No new spawning runs are being created in habitats suitable for - but never containing - anadromous fish. Striped bass are presently being stocked to manage the commercial and sport use of the fishery at an optimum yield level. Present striped bass stocking efforts are supported by both State and Federal funds and involve hatcheries established expressly for this effort. Stripers are supplied from National Fish Hatcheries for stocking in waters not landlocked, and no other sources of fish - private or out-of-state - are utilized for stocking purposes. North Carolina rivers receiving first priority for stocking efforts include the Albemarle Sound system, Roanoke, Chowan, Tar-Pamlico system, Neuse, and Cape Fear Rivers.

In addition to stocking programs, spawning runs of three anadromous species have been rehabilitated in North Carolina waters by locking procedures. Since 1962, American shad, alewife, and blueback herring have been locked through the lock and dam system in the Cape Fear River system during spring spawning runs. To date, restoration of these stocks by this method has been somewhat successful.

Habitat management in North Carolina has not involved construction of fishways or creation of new spawning sites. However, attempts have been made to increase access of five species to spawning grounds by removal of barriers and by other means. Species are striped bass, American shad, hickory shad, alewife, and blueback herring. Attempts have also been made to improve or increase nursery areas of striped bass, alewife, and blueback herring. Access by commercial and sport fishermen to spawning grounds of striped bass, American shad, hickory shad, alewife, and blueback herring are presently controlled. Water release from impoundments is regulated and controlled for anadromous fish during the spawning season. Non-point source pollutants have degraded the Roanoke and Chowan Rivers as habitat suitable for anadromous fishes, although populations are still present.

4.2.1.6 Status of Anadromous Stocks

A total of 26 river systems in North Carolina were identified by questionnaire respondees as containing anadromous populations. These areas include the Currituck and Albemarle Sounds as well as the following rivers: North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong, Alligator, Pungo, Pamlico, Tar, Neuse, Trent, Newport, White Oak, New, Cape Fear, Northeast Cape Fear, Black, and Pee Dee Rivers. Some disagreement was evidenced by the respondees as to the status of anadromous populations within these river systems and the factors possibly affecting their status.

Populations of Atlantic sturgeon were reported in nine riverine areas, and all were believed to be stable or in decline. Areas include the Albemarle Sound and the Chowan, Roanoke, Pamlico, Tar, Neuse, Cape Fear, Northeast Cape Fear, and Pee Dee Rivers. Factors possibly contributing to the decline of certain populations are dams and impoundments, industrial water intakes and discharges, sewerage outfalls, inadequate control of water release from dams, and spawning areas too accessible to fishermen.

Shortnose sturgeon are believed to be no longer present in North Carolina waters. Possible reasons for their demise include items listed for Atlantic sturgeon.

Striped bass populations were reported present in 12 rivers, and nine were listed as stable or declining. These rivers include Albemarle Sound and the Chowan, Meherrin, Roanoke, Neuse, White Oak, Cape Fear, Northeast Cape Fear, and Pee Dee Rivers. The only populations listed as increasing inhabit the Tar and Pamlico Rivers. New River striped bass stocks are threatened and may no longer be present. Factors listed as possible contributors to decline of stocks were channelization, dams, water intakes and discharges, chemical pollution, turbidity, low oxygen levels, sewerage outfalls, inadequate control of water release from dams, reduction in nursery areas, poor food availability, generally poor water quality, and spawning areas too accessible to fishermen.

American shad populations were listed as present in 14 riverine areas including the Albemarle Sound and the Chowan, Meherrin, Roanoke, Cashie, Tar, Neuse, Trent, White Oak, New, Cape Fear, Northeast Cape Fear, Black, and Pee Dee Rivers. The New River population

was listed as threatened, and status of American shad in the White Oak and Black Rivers is not known. Populations in the remaining areas were listed as declining. Factors responsible for population decline may be channelization, dredge and fill projects, dams, inadequate fishway facilities, inadequate control of water release from dams, industrial water intakes and discharges, reduction in spawning areas and nursery habitats, poor food availability, and poor water quality due to chemical pollution, turbidity, low oxygen levels, and sewerage outfalls.

Hickory shad populations were reported for 12 riverine areas and, with the exception of the White Oak and Black Rivers, were areas listed for American shad. Hickory shad in the New River were listed as threatened, and the remainder were reported as declining. Factors believed to be contributing to the decline of hickory shad stocks were similar to those listed for American shad.

Populations of alewife were listed as present in 25 of the 26 river systems; the White Oak River apparently contains no alewife. Alewife in the New River were listed as threatened. Status of alewife in the Pungo, Pamlico, North, Newport, and Black Rivers is not known. The remaining populations were reported as declining. Factors contributing to the decline of alewife stocks were similar to those listed for American shad and hickory shad.

Blueback herring are present in all 26 river systems identified by respondees. Blueback in the New River were listed as threatened. Status of populations in the Pungo, Pamlico, North, Newport, White Oak, and Black Rivers was not known. The remaining populations apparently are in decline.

4.2.1.7 Regulation and Management

State and Federal respondees disagreed on nearly all questions with regard to regulatory aspects (Question IIIB) and fisheries management (Question IIIA). They did agree, however, that decline in egg viability (Roanoke striped bass) and exploitation of parental stocks by other States or countries are important factors to the decline of anadromous fish stocks in North Carolina.

4.2.2 South Carolina

4.2.2.1 Questionnaire Respondees

Two questionnaires were sent to State agencies and both were returned. Respondees included Glenn Ulrich, Leader, Finfish Management Section, Marine Resources Division, South Carolina Wildlife and Marine Resources Department, Charleston (S); and H.J. Logan, Chief of Fisheries, South Carolina Wildlife and Marine Resources Department, Columbia (F). Following is a summary of the fishery management practices for anadromous stocks in South Carolina based on questionnaire responses from personnel listed above.

4.2.2.2 Overview

Seven anadromous species have (or had) spawning runs in South Carolina waters. These species include Atlantic sturgeon, shortnose sturgeon, striped bass (Atlantic race), American shad, hickory shad, alewife, and blueback herring. None of these species is presently included in any fishery management plan. All except alewife will be included in future plans. South Carolina has developed an anadromous species management plan for striped bass, blueback herring, and Morone hybrid but the plan has not been formally implemented. Shortnose sturgeon is the only anadromous species currently listed on the State list of endangered or threatened species. The South Carolina Wildlife and Marine Resources Department has sole responsibility in managing anadromous fish populations.

4.2.2.3 Commercial Fisheries

Four anadromous species provide an annual commercial harvest in South Carolina. These species include Atlantic sturgeon, American shad, hickory shad, and blueback herring. None of these species is managed for optimum yield. During spawning season, commercial fishing effort is restricted for American shad, hickory shad, and blueback herring, but commercial fishing on or near spawning grounds is permitted during spawning season. Commercial fishing is prohibited for shortnose sturgeon, striped bass, and Morone hybrid. Commercial gear types are regulated for Atlantic sturgeon, American shad, hickory shad, and blueback herring. There are no minimum fish lengths for legal commercial catch, but blueback herring catches are restricted by weight limits in the Cooper River.

4.2.2.4 Recreational Fisheries

Four anadromous species provide annual sport harvest in South Carolina waters, although sport fishing is not prohibited for any anadromous species. These species include striped bass, American shad, hickory shad, and blueback herring. _Morone_ hybrid is stocked in South Carolina for annual sport harvest. Only striped bass and _Morone_ hybrid are managed for sport use. Sport fishing effort is not restricted and is permitted on or near spawning grounds during spawning activity. There are no restrictions on sport fishing bait types or minimum fish lengths, but gear types are restricted for striped bass. Creel limits have been imposed for striped bass and _Morone_ hybrid.

4.2.2.5 Mitigation - Enhancement

A formal stocking plan is currently being conducted for striped bass, and State agencies are working to rehabilitate existing spawning runs to some level through stocking. No new spawning runs are being created, and runs that no longer exist are not being restored. _Morone_ hybrid is also being stocked by a formal plan. Both striped bass and _Morone_ hybrid are being stocked to manage the sport fishery at an optimum yield level. Hatcheries supported by both State and Federal funds have been established to support this stocking effort. South Carolina does not receive anadromous fish produced at National Fish Hatcheries for stocking in non-landlocked waters, and no private or out-of-state sources of fish are utilized for stocking purposes. The only South Carolina river listed as recieving first priority for stocking is the Santee River.

In addition to stocking programs, spawning runs of blueback herring have been rehabilitated in Cooper River waters by locking procedures. For the past 10 years, blueback have been locked from the Cooper River to upstream spawning grounds via the Pinopolis Navigation Lock. This program has been highly successful in rehabilitating blueback herring stocks.

Habitat management in South Carolina has not involved any construction of fishways, creation of new spawning sites, increasing accessibility to present sites, or improvement or increase of nursery areas. Access by sport and commercial fishermen to spawning grounds is not restricted. The State has an agreement with a power company to regulate or control water release from impoundments during spawning season. At present

all river systems in South Carolina are suitable for anadromous fish species.

4.2.2.6 Status of Anadromous Stocks

A total of 14 river systems in South Carolina were identified by questionnaire respondees as containing anadromous populations. These systems include the Waccamaw, Little Pee Dee, Great Pee Dee, Black, Santee, Cooper, Ashley, Edisto, Ashepoo, Combahee, Sampit, Salkehatchie, Savannah, and Lynches Rivers. Some disagreement was evidenced by the respondees as to the status of anadromous populations within these river systems and the factors possibly affecting their status.

Atlantic sturgeon populations were reported in all river systems, and the status of all populations was listed as stable or not known. Factors perhaps affecting the status of populations are dams, inadequate fishway facilities, reduced spawning habitat, and poor water quality.

Shortnose sturgeon is listed as endangered in the State, but apparently is present in all 14 river systems. The status of all populations is threatened or not known. In addition to those factors listed above for Atlantic sturgeon, respondees believed that shortnose spawning areas were too accessible to fishermen.

Striped bass populations were also reported present in all 14 river systems, four of which are declining. These include populations in the Sampit, Salkehatchie, Savannah, and Lynches Rivers. The remainder were listed as stable or not known. Factors affecting the status of striped bass populations are the same as those reported for Atlantic sturgeon.

American shad populations were reported for all river systems, and status appears to be stable. One respondee believed that the Sampit River population was increasing. Factors affecting stock status are similar to those for other species: dams, inadequate fishways, reduced spawning habitat, and poor water quality.

Hickory shad are present in all river systems, and status is stable or not known. Factors influencing stock status are the same as those listed for American shad, sturgeon, and striped bass.

Alewife are known to be present in South Carolina waters but were not reported by respondees.

Blueback herring are present in all 14 river systems. Status was listed as stable or not known. One respondee believes that the Cooper River population is increasing. Factors influencing status are dams and impoundments, inadequate fishways, reduced nursery areas, and poor water quality. Morone hybrid was reported present for the Cooper, Savannah, and Lynches Rivers. These populations were stocked by State agencies, and status of the stocks is not known.

4.2.2.7 Regulation and Management

Overfishing of anadromous stocks within State waters was considered important in contributing to stock decline within South Carolina waters. Respondees disagreed on the importance of regulatory aspects (Question IIIB) for anadromous stock protection.

4.2.3 Georgia

4.2.3.1 Questionnaire Respondees

Two questionnaires were sent to State agencies and both were returned. Respondees included James L. Music, Jr., Program Leader, Recreational Fisheries Program, Department of Natural Resources, Coastal Resources Division, Brunswick (S); and Richard M. Gennings, Chief of Fisheries, Georgia Department of Natural Resources, Atlanta (F). Following is a summary of the fishery management practices for anadromous stocks in Georgia based on questionnaire responses from personnel listed above.

4.2.3.2 Overview

Ten anadromous species or races have (or had) spawning runs in Georgia waters. These species include Atlantic sturgeon, shortnose sturgeon, striped bass (Atlantic race), striped bass (Gulf race), American shad, hickory shad, Alabama shad, blueback herring, and skipjack herring. Only Atlantic race striped bass are presently included in a fishery management plan; they also will be included in future plans along with American shad and hickory shad. Georgia has developed an anadromous species management plant for Atlantic race striped bass, American shad, hickory shad, and blueback herring. Shortnose sturgeon is the only species currently listed on the State list of endangered or threatened species. Morone hybrid is present in Georgia's coastal waters (e.g., Savannah River), apparently due to escapement from upstream reservoirs which have been heavily stocked.

The Georgia Department of Natural Resources, Game and Fish Division, has responsibility for managing anadromous fish populations.

4.2.3.3 Commercial Fisheries

Three species - Atlantic sturgeon, American shad, and hickory shad - provide an annual commercial harvest in Georgia. None of these species is presently managed for optimum yield. During the spawning season, commercial fishing effort is restricted for all three species, although commercial fishing is allowed on the spawning grounds during spawning activity. Commercial fishing is prohibited for shortnose sturgeon, both the Atlantic race and Gulf race striped bass, and Morone hybrid. Commercial gear types are regulated for Atlantic sturgeon, American shad, and hickory shad. There are no commercial fishery restrictions on the number, weight, or size of anadromous fish harvested.

4.2.3.4 Recreational Fisheries

Six anadromous species provide annual sport harvest in Georgia waters, although sport fishing is not prohibited for any anadromous species. These six species include Atlantic and Gulf races of striped bass, American shad, hickory shad, blueback herring, and skipjack herring. Morone hybrid is stocked in Georgia for annual sport harvest. Striped bass (both races), American shad, hickory shad, and Morone hybrid are presently managed for sport use. Sport fishing effort is not restricted during spawning activity and is permitted on spawning grounds. Sport fishing gear types are restricted for all species except blueback herring, but there is no restriction on bait types. None of these species has a minimum legal fish length. Creel limits have been imposed for striped bass (bo[illegible] hickory shad, an[illegible]

4.2.3.5 Mitigation-Enhancement

Atlantic race striped bass and Morone hybrid are currently being stocked under the auspices of a formal stocking plan that involves rehabilitating existing spawning runs to some level through stocking efforts. No new spawning runs are being created, and runs which no longer exist are not being restored. The current stocking program is not intended to manage the sport fishery at some optimum level. Hatcheries supported with both State and Federal funds have been established to support this stocking effort. Georgia receives

anadromous fish produced at National Fish Hatcheries for stocking in non-landlocked waters (Savannah, Ogeechee, and Satilla Rivers). No private or out-of-state sources of fish are utilized for stocking purposes. The Savannah and Ogeechee Rivers receive first priority for stocking efforts. Other methods of stock rehabilitation, such as locking, have not been used.

Habitat management in Georgia has not involved fishway construction, removal of barriers, or any other item suggested in the questionnaire. Access to spawning grounds by sport and commercial fishermen is presently not restricted. Construction of Jim Woodruff Dam has been detrimental to anadromous fish in the Flint and Chattahoochee Rivers, although anadromous fish are still present.

4.2.3.6 Status of Anadromous Stocks

Nine rivers in Georgia were identified by questionnaire respondees as containing anadromous stocks. These systems include the Savannah, Ogeechee, Altamaha, Oconee, Ocmulgee, Satilla, St. Marys, Chattahoochee, and Flint Rivers.

The status of Atlantic sturgeon is not known in all nine rivers. Factors possibly affecting stock status include channelization, dredge and fill projects, dams, location of industrial discharges, chemical pollution, thermal effluents, reduced spawning habitat and nursery areas, poor food availability, spawning areas too accessible to fishermen, and overall poor water quality.

The shortnose sturgeon was listed as threatened in all river systems within its range. Factors affecting its status are similar to those for Atlantic sturgeon.

Stocks of Atlantic race striped bass apparently are declining in all Georgia river systems. Factors possibly contributing to stock decline include channelization, dredge and fill, location of industrial discharges, chemical pollution, thermal effluents, reduced spawning habitat, poor food availability and water quality, and spawning areas to accessible to fishermen.

The status of Gulf race striped bass was not known for Gulf coast river systems in Georgia.

American shad stocks in the Ogeechee, Satilla, and St. Marys Rivers were listed as declining. The status of shad stocks in the Savannah and Altamaha was not known. Factors possibly contributing to stock decline are the same as those reported for sturgeon.

The status of hickory shad is not known in Georgia, and factors affecting its status are similar to those listed for sturgeon and American shad.

Alewife was reported as "probably never present" in Georgia rivers. Skipjack herring occurs only in the Chattahoochee and Flint Rivers, which drain into the Gulf of Mexico. The status of skipjack herring stocks appears to be stable.

Blueback herring are present in all nine rivers but the status of stocks is not known. Inadequate information was available to determine possible factors affecting stock status.

4.2.3.7 Regulation and Management

With respect to regulatory aspects, the marine representative (S) reported that the lack of coordinated effort between State and Federal agencies, between bordering States, and among agencies within the State of Georgia is important to the decline of anadromous fish stocks within the State. The freshwater respondee (F) believed that lack of coordinated effort among State agencies is not a contribution to stock decline. Overfishing within State waters apparently is also a problem. Federal laws, regulations, and policies regarding protection of anadromous stocks were believed adequate. The lack of funding to maintain current management programs was believed important in contribution to the decline of anadromous stocks.

4.2.4 Florida

4.2.4.1 Questionnaire Respondees

Three questionnaires were sent to State and Federal agencies and all three were returned. Respondees included Roy Williams and Alan Huff, Biologist Supervisor II and Senior Biologist for the Department of Natural Resources, St. Petersburg (S); Forrest Ware, Assistant Director, Division of Fisheries, Florida Game and Freshwater Fish Commission (F); and Craig R. O'Connor for Harold B. Allen, Acting Regional Director, National Marine Fisheries Service, Southeast Region, St. Petersburg. The Federal response involved a critique

and review of the questionnaire, and specific answers were not given to questions posed in the questionnaire. The following summary of the fishery management practices for anadromous stocks in Florida are based only on responses from State personnel listed above.

4.2.4.2 Overview

Ten anadromous species or races have (or had) spawning runs in Florida waters. These species include Atlantic sturgeon, shortnose sturgeon, Gulf sturgeon, Atlantic race striped bass, Gulf race striped bass, American shad, hickory shad, Alabama shad, blueback herring, and skipjack herring. Gulf sturgeon is the only anadromous species presently included in a fishery management plan, and Gulf sturgeon and both races of striped bass will probably be included in future plans. Florida has developed an anadromous species management plan for Atlantic race striped bass. Shortnose sturgeon is currently the only anadromous species listed on the State list of endangered or threatened species. *Morone* hybrid has been introduced into Florida's coastal waters through stocking. The Florida Department of Natural Resources is responsible for management of clupeid and sturgeon stocks, and the Florida Game and Freshwater Fish Commission is responsible for management of striped bass in fresh water.

4.2.4.3 Commercial Fisheries

Five anadromous species - Atlantic sturgeon, Gulf sturgeon, American shad, hickory shad, and blueback herring - provide an annual commercial harvest in Florida. During spawning season, commercial fishing effort is restricted for Atlantic and Gulf sturgeons, American shad, and blueback herring. Commercial fishing is prohibited on or near spawning grounds for American shad, hickory shad, and blueback herring, and is prohibited altogether for Atlantic race striped bass, Gulf race striped bass, and *Morone* hybrid. Commercial gear types are regulated for four species - American shad, hickory shad, blueback herring, and Gulf sturgeon. There are no commercial fishery restrictions on the number, weight, or size of anadromous fish harvested.

4.2.4.4 Recreational Fisheries

Five anadromous species provide annual sport harvest in Florida waters, although sport fishing is not prohibited for any anadromous species. These species include Atlantic race striped bass, Gulf race striped bass, American shad, hickory shad, and Alabama shad. *Morone* hybrid is stocked

in Florida waters for sport use. All are presently managed for sport use. Sport fishing effort is restricted for both races of striped bass, American shad, and hickory shad during spawning season, but fishing is allowed on spawning grounds at this time. There are no restrictions on sport fishing gear types or bait types, and a minimum legal size (15" TL) applies only for Atlantic race striped bass. Creel limits have been imposed for Atlantic race striped bass (6), Gulf race striped bass (6), American shad (10), and Morone hybrid (6).

4.2.4.5 Mitigation-Enhancement

Florida presently has a formal plan for stocking fish in coastal waters. Gulf race striped bass are being planted in cooperation with the U.S. Fish and Wildlife Service. Atlantic race striped bass and Morone hybrids are stocked by formal plan by the Game and Freshwater Fish Commission. Atlantic race striped bass runs are being rehabilitated, but no new runs are being created. Only the Morone hybrid stocking program is intended to manage the sportfishery at some optimum level. Hatcheries supported from both State and Federal funds have been established to support this stocking effort. Florida does receive both Atlantic race and Gulf race striped bass produced at National Fish Hatcheries for stocking in non-landlocked waters. Morone hybrid is supplied by the Florida Game and Freshwater Fish Commission for stocking purposes. Rivers that receive first priority for stocking include the Apalachicola, Escambia, and Ocklockonee. Although somewhat successful, the St. Johns River stocking program was discontinued after eight years. Atlantic race striped bass have been stocked in the Ocklockonee River for 12 years, and the program has been highly successful.

Habitat management in Florida has not utilized any of the practices listed in the questionnaire. However, access to spawning grounds of American shad, hickory shad, and blueback herring has been restricted to commercial fishermen. Pollution and construction of a dam on the Hillsborough River has made the river system no longer suitable for anadromous fish species.

4.2.4.6 Status of Anadromous Stocks

Ten river systems in Florida were identified by questionnaire respondees as containing anadromous fish. Atlantic coast rivers include the St. Marys, Nassau, St. Johns and Tomoka Rivers, and Pellicer Creek. Gulf coast rivers include the Hillsborough, Suwannee, Apalachicola, Ocklockonee, and Escambia. Respondees differed in opinion as to the status of anadromous stocks in these rivers.

Atlantic sturgeon were reported in the St. Marys, Nassau, and St. Johns Rivers. St. Marys sturgeon were listed as threatened/stable, Nassau sturgeon as never present/stable, and St. Johns sturgeon as declining. Factors possibly contributing to stock decline include dams, location of industrial discharges, reduced spawning habitat and nursery areas, poor water quality, non-point source pollutants, and overfishing (for sturgeon).

Shortnose sturgeon is listed as threatened in the St. Johns River, and its status is not known in the St. Marys, Nassau, Apalachicola, and Ocklockonee Rivers. No information was available to predict factors affecting its status in Florida waters.

Gulf sturgeon status was reported for five Gulf coast river systems. Populations in Hillsborough and Ocklockonee Rivers are no longer present. The Suwannee River population was listed as stable, and those in the Apalachicola River are threatened or in decline. Factors possibly contributing to stock decline are channelization, dams, location of industrial discharges, proposed phosphate strip mining, inadequate fishways, reduced spawning habitat and nursery areas, poor water quality, and overfishing.

Atlantic race striped bass stocks were reported in the St. Marys, Nassau, St. Johns, and Ocklockonee Rivers. St. Marys and Nassau populations may be stable or in decline. Populations in the St. Johns and Ocklockonee Rivers may be increasing (due to stocking). Factors affecting stock status may be channelization, dredge and fill projects, bulkheading, dams, location of industrial discharges, agricultural drainage, chemical pollution, low oxygen levels, sewerage outfalls, reduced spawning habitat and nursery areas, and poor water quality.

Gulf race striped bass was reported only for the Apalachicola River, and its status is either threatened or stable. Factors affecting its status are channelization, dredge and fill projects, bulkheading, and chemical pollution.

American shad were reported in the St. Marys, Nassau, St. Johns, and Tomoka Rivers, and Pellicer Creek. Populations in Pellicer Creek and Tomoka River are declining, and American shad stocks in the St. Marys and St. Johns Rivers are either stable or declining. The status of Nassau River shad may be stable. Factors affecting stock status in Florida waters may be

channelization, dredge and fill projects, bulkheading, dams, water intakes, location of industrial discharges, agricultural runoff, chemical pollution, low oxygen levels, sewerage outfalls, non-point source pollutants, reduced freshwater input to estuaries, reduced spawning and nursery areas, poor food availability and water quality, spawning areas too accessible to commercial fishermen, and overfishing.

Hickory shad populations are present in the St. Marys, Nassau, and St. Johns Rivers (status not known), Tomoka River (declining), and Pellicer Creek (status not known). Factors affecting population status may be channelization, industrial water intakes, low oxygen levels, sewerage outfalls, non-point source pollutants, reduced freshwater input to estuaries, reduced spawning and nursery grounds, poor water quality and food availability, and spawning areas too accessible to fishermen.

Alabama shad was reported only for the Apalachicola River, and its status may be stable or declining. Factors affecting its status may be channelization, dams, and reduction in spawning habitat.

Blueback herring are present in five Atlantic coast rivers. The status of blueback in the St. Marys and Nassau Rivers is not known, Tomoka and St. Johns River populations are declining, and the status of blueback in Pellicer Creek is not known. Potential causes for decline include channelization, industrial water intake, sewerage outfalls, reduced freshwater input to estuaries, reduced spawning and nursery habitat, poor water quality and food availability, and spawning areas too accessible to fishermen.

River systems and status were not reported for skipjack herring.

4.2.4.7 Regulation and Management

Some disagreement was apparent with regard to regulatory aspects. The marine representative believed lack of coordination among agencies within the State of Florida and the lack of funding to develop new management programs were important to the decline of anadromous fish in State waters. The freshwater representative believed these two aspects do not contribute to declining stocks. Disagreement was also apparent on aspects of overfishing within State waters, competition by other species, and exploitation of parental stocks by other States or countries as they pertain to declining anadromous stocks in Florida waters.

4.2.5 Alabama

4.2.5.1 Questionnaire Respondees

Two questionnaires were sent to State agencies for completion and both were returned. Respondees included Walter M. Tatum, Chief Marine Biologist with the Alabama Department of Conservation and Natural Resources, Division of Marine Resources, Gulf Shores (S); and Barry W. Smith, Fisheries Biologist IV with the Department of Conservation and Natural Resources, Game and Fish Division, Montgomery (F). Following is a summary of the fishery management practices for anadromous stocks in Alabama based on questionnaire responses from these personnel.

4.2.5.2 Overview

Six anadromous species or races have (or had) spawning runs in Alabama waters. These species include Gulf sturgeon, shortnose sturgeon, both the Atlantic and Gulf races of striped bass, Alabama shad, and skipjack herring. State respondees also listed the Alabama shovelnose sturgeon as an anadromous spawner. Alabama presently has an anadromous species management plan for striped bass. All except shortnose sturgeon will probably be included in future plans. Gulf sturgeon and Alabama shovelnose sturgeon are the only species currently on the State list of endangered or threatened species. Morone hybrid has been introduced into Alabama waters through stocking. The Game and Fish Division and the Marine Resources Division have joint responsibility for managing anadromous fish populations in Alabama.

4.2.5.3 Commercial Fisheries

None of the anadromous species provide a commercial harvest in Alabama. There is no restriction of commercial fishing during spawning season. There are restrictions prohibiting the use of commercial fishing gear within one-half mile downstream of any lock or dam. Commercial fishing is prohibited for Gulf and shortnose sturgeon. There are no minimum fish lengths for legal commercial catch; however, a three-inch bar mesh is minimum legal net size for freshwater. No Morone sp. may be taken commercially in freshwater.

4.2.5.4 Recreational Fisheries

Three anadromous species provide an annual sport harvest: Atlantic race striped bass, Gulf race striped bass, and skipjack herring. Morone hybrid is stocked in

Alabama waters for annual sport harvest. Sportfishing for Gulf sturgeon is prohibited in Alabama. At present, Morone hybrid and both races of striped bass are managed for sport use. Sport fishing effort is not restricted during spawning season and is permitted on the spawning grounds during spawning activity. Sport fishing gear types and bait types are not restricted, and there is no legal size for a sport catch. Creel limits have been imposed for both races of striped bass (6) and Morone hybrid (6) in fresh water.

4.2.5.5 Mitigation-Enhancement

Both races of striped bass and Morone hybrid are currently being stocked under the auspices of a formal stocking plan that involves rehabilitating existing spawning runs of Atlantic race striped bass and Morone hybrid and restoring spawning runs that no longer exist for these species. No new runs are being created. The current stocking program is intended to manage use of the Atlantic race striped bass fishery at some optimum yield level. Hatcheries supported with both State and Federal funds have been established to support this stocking effort. Alabama receives both Atlantic and Gulf races of striped bass producted at National Fish Hatcheries for stocking in non-landlocked waters, and additional Atlantic race striped bass and Morone hybrid are provided by private or out-of-state sources for stocking purposes. A total of 12 rivers in Alabama receive first priority for stocking efforts. These rivers are the Coosa, Tallapoosa, Alabama, Tennessee, Chattahoochee, Tombigbee, Perdido, Bon Secour, Magnolia, Fish, Dog, and Fowl Rivers. Atlantic race striped bass have been stocked in the Alabama River for 13 years and in the Perdido River for 10 years; the effectiveness of these programs cannot be determined at this time.

Habitat management in Alabama does not involve construction of fishway facilities, creation of new spawning sites, or attempts to increase fish access to spawning grounds. However, Alabama is attempting to improve or increase nursery areas for all anadromous species and Morone hybrid. Portions of the Mobile River system are affected by industrial pollution and are no longer suitable for anadromous fish.

4.2.5.6 Status of Anadromous Stocks

Twelve riverine areas in Alabama were identified by questionnaire respondees as containing anadromous stocks. These coastal areas include the Alabama,

Tombigbee, Perdido, Bon Secour, Fish, Magnolia, Dog, Fowl, Tennessee, Chattahoochee, Coosa, and Tallapoosa Rivers.

Gulf sturgeon were reported as once inhabiting all twelve rivers. Populations of Gulf sturgeon are probably no longer present in the Alabama, Tombigbee, Tennessee, Coosa, and Tallapoosa Rivers. Population status in the remainder of the rivers is not known. Factors contributing to the demise of Gulf sturgeon may have been bulkheading, dams and impoundments, location of industrial discharges, road construction, low oxygen levels, sewerage outfalls, inadequate fishway facilities, inadequate control of water release from dams, reduced spawning and nursery grounds, poor water quality, and poor food availability.

Status of the shortnose sturgeon is not known in Alabama waters. Respondees reported its presence in the Alabama, Tombigbee, Perdido, Bon Secour, Fish, Magnolia, Dog, and Fowl Rivers. Factors affecting its status may be dams, location of industrial discharges, road construction, low oxygen levels, sewerage outfalls, inadequate fishway facilities, poor food availability, and poor water quality.

Atlantic race striped bass was reported present in 11 river systems in Alabama waters (no response was given for the Chattahoochee River), and all populations are increasing due to stocking efforts.

Gulf race striped bass was listed for all river systems except the Chattahoochee and Tennessee Rivers. Populations in the Coosa, Tallapoosa, and Alabama Rivers may no longer be present, and the Tombigbee Gulf striper population is in decline. Population status in the remainder of the rivers is not known. Factors affecting its status may be bulkheading, dams and impoundments, location of industrial discharges, road construction, low oxygen levels, sewerage outfalls, inadequate control of water release from dams, reduced spawning and nursery grounds, and poor water quality.

The skipjack herring is present in all 12 river systems. Stable populations inhabit the Tennessee and Chattahoochee Rivers. Alabama and Tombigbee River populations may be stable or in decline, and populations in the Coosa and Tallapoosa Rivers are in decline. The status of Alabama shad in the remainder of the rivers is not known. Factors affecting stock status may be

bulkheading, dams and impoundments, location of industrial discharges, road construction, low oxygen levels, sewerage outfalls, inadequate fishway facilities, reduced spawning and nursery habitat, poor food availability, and poor water quality.

The Alabama shad was listed for all rivers but the Tennessee. Coosa River and Tallapoosa River populations are declining. Alabama shad populations in the Chattahoochee, Alabama, and Tombigbee Rivers are stable. Status of the remainder of the populations is not known. Factors affecting stock status are the same as those reported for skipjack herring.

4.2.5.7 Regulation and Management

Both questionnaire respondees were in basic agreement with regard to regulatory and management aspects. Both believed that the lack of funding to develop new programs and the lack of funding to maintain current programs were important in the decline of anadromous stocks in Alabama waters. Both respondees were also in agreement that International, Federal, State, and local laws, regulations, and policies were adequate in meeting the needs for management of anadromous stocks.

4.2.6 Mississippi

4.2.6.1 Questionnaire Respondees

Two questionnaires were sent to State agencies and both were returned. Respondees included Thomas D. McIlwain, Assistant Director for Fisheries Research and Management, Gulf Coast Research Laboratory; and Barry O. Freeman, Chief of Fisheries, Mississippi Game and Fish Commission, Jackson. Following is a summary of the fisheries management practices for anadromous stocks in Mississippi based on questionnaire responses from personnel listed above.

4.2.6.2 Overview

Three anadromous species have or had spawning runs in Mississippi waters. These species include Gulf sturgeon and both the Atlantic race and Gulf race striped bass.

None of these species are presently included in a fishery management plan, but all probably will be included in future management plans. Mississippi does not have an anadromous species management plan, but there are plans to develop one for both races of striped bass. No

anadromous species are currently listed on the State list of endangered or threatened species. The Mississippi Department of Wildlife Conservation has responsibility for managing anadromous fish populations.

4.2.6.3 Commercial Fisheries

No anadromous fish provide any commercial harvest in Mississippi. Commercial fishing is prohibited for these species in freshwater but not in saltwater.

4.2.6.4 Recreational Fisheries

Both Atlantic race and Gulf race striped bass provide annual sport harvest in Mississippi waters, although sport fishing is not prohibited for any anadromous species. Sport fishing effort is not restricted during spawning activity and is permitted on spawning grounds. Sport fishing gear types and bait types are not restricted, but there is a minimum fish length and creel limit for these species for legal sport catch.

4.2.6.5 Mitigation-Enhancement

Both races of striped bass are currently being stocked under the auspices of a formal stocking plan. This plan calls for rehabilitating existing spawning runs, restoring spawning runs no longer in existence, and creating new spawning runs in river systems that appear conducive to these species. The current stocking program is intended to manage the sport fishery at some optimum level. Hatcheries, supported with both State and Federal funds, have been established to support this stocking effort. Mississippi receives both races of striped bass from the Federal Government, produced at National Fish Hatcheries, for stocking in waters that are not landlocked. Mississippi also depends on private or out-of-state sources of these species for stocking purposes. Riverine areas receiving first priority for stocking efforts include the Pascagoula, Biloxi, Tchouticabouffa, Wolf, Jourdan, and Tallahatchie Rivers, and Okatibbee Creek. The stocking programs for Atlantic race striped bass have involved Tchouticabouffa and Biloxi Rivers for the past 10 years, and Jourdan and Wolf Rivers for the past six years. These programs have been highly successful. Gulf race striped bass were stocked in the Pascagoula River for one year and the success of the program cannot be determined at this time. Other methods of stock rehabilitation, such as locking, have not been used.

Habitat management in Mississippi has not involved any items suggested in the questionnaire. Access to spawning grounds by sport and commercial fishermen is presently not restricted. Respondees indicated Mississippi coastal rivers to be in better condition today than 15 to 20 years ago.

4.2.6.6 Status of Anadromous Stocks

Six river systems in Mississippi were identified by questionnaire respondees as containing anadromous stocks. These systems include the Pascagoula, Tchouticabouffa, Biloxi, Wolf, Jourdan, and Pearl Rivers.

The status of Gulf sturgeon and Gulf race striped bass populations is not known for all six river systems. Poor water quality was listed as a very important contributor to the demise of both species. Atlantic race striped bass stocks are increasing for five of the six river systems due to stocking. Status of this species in the Pascagoula River was not reported.

4.2.6.7 Regulation and Management

One of the respondees believed that the lack of funding to develop new management programs and the lack of funding to maintain current management programs are important to the decline of anadromous fish stocks within the State.

4.2.7 Louisiana

4.2.7.1 Questionnaire Respondees

Two questionnaires were sent to State agencies and one was returned by Arthur M. Williams, Anadromous Project Leader, Louisiana Department of Wildlife and Fisheries, Terriday. Following is a summary of the fishery management practices for anadromous stocks in Louisiana based on the questionnaire response by Williams.

4.2.7.2 Overview

Five anadromous species - Gulf sturgeon, Atlantic race and Gulf race striped bass, skipjack herring, and Alabama shad - have or had spawning runs in Louisiana waters. Gulf sturgeon, Alabama shad, and skipjack herring are not presently included in a fishery management plan. Gulf sturgeon and Gulf race striped bass will probably be included in future management plans. Currently, no anadromous species are on the State list of endangered or

threatened species. *Morone* hybrids have been introduced into coastal waters through stocking of lakes that are tributary to coastal streams but have not been stocked directly into coastal waters. The Louisiana Department of Wildlife and Fisheries has responsibility for managing anadromous fish populations.

4.2.7.3 Commercial Fisheries

Skipjack herring is the only anadromous species that provides an annual commercial harvest in Louisiana. This species is not presently managed for optimum yield. Commercial fishing is prohibited for *Morone* hybrid and both races of striped bass. Commercial fishing effort is not restricted during spawning season; it is allowed on the spawning grounds during spawning season and spawning activity. There are no commercial fishing restrictions on gear type utilized, or on the number, weight, or size of anadromous fish harvested.

4.2.7.4 Recreational Fisheries

Morone hybrid and both races of striped bass provide annual sport harvest in Louisiana waters, although sport fishing is not prohibited for any anadromous species. These three species are presently managed for sport use. Sport fishing effort is not restricted during spawning activity and is permitted on the spawning grounds. There are no sport fishing restrictions on gear types, bait types, or minimum legal fish lengths for these species. However, creel limits have been imposed for *Morone* hybrid and both races of striped bass.

4.2.7.5 Mitigation-Enhancement

Morone hybrid and both races of striped bass are currently being stocked under the auspices of a formal stocking plan. Spawning runs of Atlantic race striped bass are being rehabilitated where in existence, restocked where no longer in existence, and created in river systems that appear conducive to this species. The current stocking program is not intended to manage the sport fishery at any optimum level. Hatcheries have been established to support Atlantic race striped bass stocking efforts. Commercial and/or sport stamp revenues and State and Federal funds support stocking efforts. Atlantic race striped bass and *Morone* hybrid, produced at National Fish Hatcheries, are received from the Federal Government for stocking in waters that are not landlocked, and no private or out-of-state sources

of fish are utilized for stocking purposes. Riverine areas receiving first priority for stocking efforts include Bayou LaCombe and the Tchefuncte, Pearl, Mermentau, and Calcasieu Rivers. Stocking of Atlantic race striped bass and Morone hybrid was conducted in the Mississippi River from 1965 through 1979, and in the Atchafalaya River system from 1965 through 1980. Both stocking programs were highly successful.

Habitat management in Louisiana has not involved any of the items suggested in the questionnaire. Access to spawning grounds by sport and commercial fishermen is presently not restricted. Industrial pollution in the Vermillion River has caused the system to be no longer suitable for anadromous fish.

4.2.7.6 Status of Anadromous Stocks

Twelve river systems in Louisiana were identified as containing anadromous stocks. These systems include the Pearl, Tchefuncte, Tangipahoa, Tickfaw, Amite, Mississippi, Atchafalaya, Vermillion, Mermentau, Calcasieu, and Sabine Rivers and Bayou LaCombe. Gulf sturgeon, Alabama shad, and skipjack herring were reported for all twelve river systems. All populations of skipjack herring are believed to be stable, and the status of Gulf sturgeon and Alabama shad is not known. Factors affecting status of the Gulf sturgeon include channelization, dams, and impoundments. Inadequate information was available to determine factors affecting the status of Alabama shad and skipjack herring.

Gulf race striped bass are present in the Pearl, Tchefuncte, Tangipahoa, Tickfaw, Amite, and Mississippi Rivers and Bayou LaCombe. Status of the Gulf race striped bass is not known, and factors affecting its status include channelization, dams, and impoundments.

Atlantic race striped bass stocks are increasing in eleven of the twelve river systems due to stocking. The status of Vermillion River stripers is not known.

4.2.7.7 Regulation and Management

Williams believed that overabundance of natural predators may be a very important cause in the decline of anadromous stocks in Louisiana waters. Williams also believed that International, Federal, State, and local laws, regulations, and policies were adequate in protecting anadromous stocks.

4.2.8 Texas

One questionnaire was sent to the State of Texas and was returned by Ernest G. Simmons, Chief of Inland Fisheries, Texas Parks and Wildlife Department, Austin.

Texas currently has a very active stocking program for striped bass, and spawning populations have been established in two areas in wet years. However, there is virtually no control over water releases from impoundments, and the fishery suffers in dry years. All stripers are of the Atlantic strain, and Texas is quite interested in working with the Gulf strain in the lower sections of certain rivers. *Morone* hybrid is stocked strictly on a put, grow, and take basis.

5. RESEARCH NEEDS

5.1 Specific Research Needs Identified by State and Federal Agencies

Suggestions for research required to adequately manage anadromous resources were developed from the questionnaire returned by State and Federal agencies. Research needs were divided into four categories: 1) status of anadromous populations, 2) life history information, 3) identification of major factors contributing to the changes in fish abundance, and 4) artificial propagation of anadromous species. Research needs listed below have been identified by the State abbreviation or represented by the single letter "S" for the U.S. Fish and Wildlife Service.

5.1.1 Status of Anadromous Fish Populations

S: Develop better techniques for enumeration of striped bass fry in hatcheries and the wild.

SC: Collect catch-effort data from commercial fishermen over a period of at least six years (e.g., American shad) for all major river systems within the State to establish population trends.

GA: Document population levels to determine what is happening offshore to anadromous species, what rivers the various populations enter, and the degree to which problems within one State affect populations in another.

FL: Demonstrate relationships between stock and recruitment.

AL: Determine the importance of anadromous sportfishes, present population levels, and utilization by commercial and recreational fishermen.

AL: Carry out an assessment program to determine the magnitude of striped bass stocks, the major spawning areas, movements, and mortality.

NC: Determine relative abundance of juveniles in nursery areas.

5.1.2 Life History Studies

S: Identify and catalog all strains of striped bass by morphological and biochemical profiles.

S: Catalog life history parameters and evaluate physiological parameters of various strains of striped bass in the wild.

S: Develop food selectivity indicies for American shad and river herring.

NC: Determine reasons for reduced viability of striped bass eggs in the Roanoke River.

FL: Determine the effect of eutrophication and competition of juvenile clupeids with juvenile gizzard shad, which is much more abundant now than historically.

FL: Characterize the spawning habitat of Gulf sturgeon in the Suwannee River, including determination of the water quality necessary to maintain current levels of spawning, egg production/viability, and postlarval survival.

AL: Determine the role of anadromous herrings on the survival and general well-being of striped bass.

LA: Determine which river systems now have reproducing populations of anadromous species.

LA: Locate spawning sites of anadromous species.

5.1.3 Identification of Major Factors Contributing to Changes in Fish Abundance.

S: Determine levels of contamination in eggs, embryos, and larvae of striped bass, and select striped bass strains best-fitted for survival in changing and varying environments.

S: Determine the effect of small-scale hydroelectric development on Southeastern anadromous fishery resources.

NC: Determine the effects of degraded conditions on the western Albemarle Sound nursery area.

NC: Analyze past and current data to assess population dynamics, stock conditions, mortality, etc., and carry out selected tagging to contribute to these efforts.

GA: Conduct studies to provide new information concerning factors affecting fluctuating shad stocks, and develop population models such as stock recruitment curves, which would serve as a basis for reaching shad management decisions.

FL: Determine the effect of entrainment on eggs, larvae, and juveniles in electric generating station cooling systems.

5.1.4 Artificial Propagation of Anadromous Species

S: Develop techniques for mass-marking large numbers of small anadromous fish.

S: Develop new fish culture techniques for rearing sensitive species (e.g., American shad).

S: Evaluate chemical or biological control of pests in fish culture rearing ponds without destroying the food chain.

5.2 Outline of Research Needs for Management Planning

The following it an outline of information needed for most anadromous fish species before an integrated management plan can be developed and initiated. For several southeastern anadromous species, adequate studies have already been completed in many of the areas included in the outline, but for other species major research efforts will be required. This outline can assist in prioritizing research needed before a final management plan can be developed.

I. Status of Anadromous Fish Populations in Region 4

   A. Determine the abundance and distribution of all anadromous fish stocks

   B. Review past and present commercial and sport fishing catch-effort records to determine population trends for each species and for each major river system

   C. Determine the socio-economic utilization of past and present stocks

II. Critical Life History Information

   A. Inventory all life stages for each anadromous fish species

      1. Standardize the collection, reporting, and analysis of data

         a. Review and analyze existing literature and data

         b. Coordinate State and Federal efforts

         c. Develop sampling techniques and gear needed to create a quantitative time series data base

      2. Monitor present and future populations

         a. Adult populations

            1) Determine migration routes and patterns

            2) Identify and characterize spawning grounds

            3) Identify factors controlling seasonality of spawning, gonadal development, etc.

            4) Determine specific characteristics of adult populations such as abundance, sex ratio, age distribution, size distribution, etc.

b. Early life history stages (eggs and larvae)

1) Determine relative abundance, distribution, movements, etc.

2) Determine factors controlling growth, survival, etc.

c. Juvenile stage

1) Determine relative abundance, distribution, and movements

2) Determine factors controlling survival, growth, etc.

B. Conduct population dynamics studies

1. Analyze catch and sampling efforts (commercial, sport, and other) for the following aspects:

a. Age and size composition

b. Fecundity

c. Growth rates (at all stages)

d. Sex ratios

e. Mortality rates (at all stages)

f. Age at maturity

g. Other aspects

2. Determine the relationships between number of adults and recruitment to the fishery

3. Evaluate relationships between native populations and introduced (hybrid and exotic) populations

4. Develop mass-marking techniques

5. Determine relationships of past stocking efforts to recruitment

C. Identify critical environmental requirements at all life stages. Examples are: temperature, salinity, bottom habitat, water flow, water quality, food availability, competition, predation, etc.

III. Major Factors Contributing to Changes in Fish Abundance

A. Determine effects of altered physical habitats on fish populations. Examples of physical changes are: dams, channelization, dredge and fill projects, bulkheads, industrial intakes and discharges, road construction, inadequate fishways and control of water releases from dams, multiple use of waterways (industrial, municipal, and agricultural), shipping ports, phosphate mining, energy development projects, etc.

B. Determine the effects of overfishing by the following methods:

1. Commercial fishing

2. Sportfishing

3. Fishing on spawning grounds

4. Illegal fishing

C. Determine effects of contamination (point and non-point source pollutants)

1. Identify and determine levels of contaminants in environments utilized by anadromous fish. Examples of possible contaminants include: industrial wastes, municipal sewage and wastes, insecticides, agricultural chemicals and wastes, wastes from energy development (oil, gas, and coal), generally-poor water quality, thermal pollution, and acid rain.

2. Determine contaminant residues in body tissues of various life stages

3. Correlate levels of contaminants to the survival of eggs, larvae, and juveniles, and determine effects on behavior, fecundity, egg viability, and osmo-regulatory systems in adults

IV. Aritificial Propagation for Restoration of Anadromous Species

A. Determine water quality factors (physical, chemical, and biological) required to propagate each species

B. Improve fish culture methods

1. Conduct research on nutritional requirements and feeding methods

2. Develop more efficient methods for mass production

3. Develop methods to control chemical, physical, and biological conditions such as pH, oxygen, algal blooms, growth of aquatic vegetation, etc.

C. Improve artificial spawning and holding techniques

1. Develop techniques for cryogenic preservation of sperm

2. Develop techniques for hormonal injection

6. RECOMMENDATIONS

The following recommendations were developed as a result of the questionnaire completed by State and Federal personnel who are involved with anadromous fish problems in drainage basins throughout the Southeastern United States. Since some anadromous stocks are found beyond the borders of a single State and may enter territorial or international waters, the recommendations presented in this section should be examined by experts of involved jurisdictional units and research personnel before they are adopted. Due to the complexity of the problem, development and presentation of detailed plans by the U.S. Fish and Wildlife Service at this time, without the input of other agencies, could further fragment the total effort.

1. A goal or purpose statement should be accepted.

Restore and/or maintain stocks of anadromous fish of Southern States at levels suitable for optimum yields, where optimum yield is defined as the "deliberate melding of biological, economic, social, and political values designed to produce the maximum benefit to society from stocks that are sought for human use, taking into account the effect of harvesting on dependent and associated species" (Roedel 1975).

2. All anadromous species should be considered in management plans developed by the Southern States, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service.

3. Two areas (South Atlantic and Gulf) should each have a coordination committee for Anadromous Species Management. The involved States should have a marine and freshwater representative on the committee. In addition, both committees should include representatives of the National Marine Fisheries Service and the U.S. Fish and Wildlife Service. The South Atlantic Committee should be designated to represent North Carolina, South Carolina, Georgia, and Florida. The Gulf Committee should represent Florida, Alabama, Mississippi, Louisiana, and Texas.

The Committees are recommended to function in the following manner:

a. Committee chairmanship should rotate among member agencies.

b. A permanent employee should be retained to conduct the adminsitrative functions of the Committee.

c. Each State representative should have the support of both research and management from their State.

d. The Committee should select a Technical Subcommittee to formulate policies and goals, and coordinate activities. A Scientific Subcommittee should also be selected to standardize sampling efforts, collection of data, and coordinate support personnel.

e. The goals of the Committees should be to 1) develop and implement management plans for the South Atlantic and Gulf, 2) coordinate activities of fisheries agencies, and 3) obtain support and funding for the work.

f. The Committees should work closely with State and Federal Management Boards, Atlantic and Gulf States, Marine Fisheries Commissions, and the South Atlantic and Gulf of Mexico Fishery Management Councils.

g. Committees should incorporate in their plans any previous plans developed for their area (e.g., Ulrich et al. 1979. Development of Fishery Management Plans for Selected Anadromous Fishes South Carolina/Georgia). Committees should also consider other efforts being conducted as indicated in Section 3 subsections of this Document entitled "Protection and Management" (3.1.13, 3.2.13, 3.3.13, through 3.11.13).

4. The anadromous fisheries of the South Atlantic and Gulf should be described in detail.

5. Anadromous fish populations and habitats should be identified, preserved, and improved.

6. Improved methods used to collect anadromous fishery statistics should be developed to include catch, effort, price, and cost.

7. Detailed biological studies, such as those described in Section 5 "Research Needs" of this Document, should be implemented.

8. Research concerning the development of various management strategies should be conducted. Investigations could:

a. Determine the optimum sizes of harvests.

b. Determine the extent and causes of fluctuations in abundances and yields through monitoring procedures.

c. Assess values of methods used to enhance or restore other anadromous fish populations throughout the United States and foreign countries and determine their applicability to Southern U.S. fisheries.

9. Extension education to the anadromous fishery industry and to user groups should be provided. The following subject areas should be addressed:

a. Methods of management for efficient harvesting.

b. Collection and interpretation of marketing information to utilize the anadromous resources in a more efficient manner.

c. Fishery alternatives due to problems with over-exploitation of stocks.

LITERATURE CITED

Ackman, R.G., C.A. Eaton, and B.A. Linke. 1975. Differentiation of freshwater characteristics of fatty acids in Marine specimens of the Atlantic sturgeon, Acipenser oxyrhynchus. NOAA Fish. Bull. 73:838-845.

Adams, J.G. 1970. Clupeids in the Altamaha River, Georgia. Ga. Game Fish Comm., Contrib. Ser. 20, 27 p.

Adams, J.G. and M.W. Street. 1969. Notes on the spawning and embryological development of blueback herring, (Alosa aestivalis Mitchell), in the Altamaha River, Georgia. Ga. Game Fish Comm., Coastal Fish. Off., Contrib. Ser. No. 16, 14 p.

Albrecht, A.B. 1964. Some observations on factors associated with survival of striped bass eggs and larvae. Calif. Fish Game 50(2):100-113.

Appy, R.G. and M.J. Dadswell. 1978. Parasites of Acipenser brevirostrum LeSueur and Acipenser oxyrhynchus Mitchell (Osteichthyes: Acipenseridae) in the Saint John River Estuary, N.B., with a description of Caballeronema pseudoargumentosus Sp. N. (Nematoda: Spirurida). Can. J. Zool. 56(6):1382-1391.

Atkinson, C. E. 1951. Feeding habits of the adult shad (Alosa sapidissima) in freshwater. Ecology 32:556-557.

Auld, A.H. and J.R. Schubel. 1978. Effects of suspended sediment on fish eggs and larvae: a laboratory assessment. Estuarine Coastal Mar. Sci. 6:153-164.

Baker, W.D. 1968. A reconnaissance of anadromous fish runs into the inland fishing waters of North Carolina. Completion report for Proj. AFS-3. N.C. Wildl. Res. Comm., 33 p.

Barkaloo, J.M. 1961. Distribution and abundance of striped bass Roccus saxatilis (Walbaum) on the Florida Gulf coast. Proc. Annu. Conf. Southeast Assoc. Game and Fish Comm. 15:223-226.

Barkaloo, J.M. 1967. Florida striped bass. Fla. Game Freshwater Fish Comm., Fish. Bull. No. 4, 24 p.

Barkaloo, J.M. 1970. Taxonomic status and reproduction of the striped bass Morone saxatilis in Florida. U.S. Fish Wildl. Serv., Tech. Paper No. 44, 16 p.

Bason, W.H. 1971. Ecology and early life history of striped bass, Morone saxatilis, in the Delaware Estuary. Ichthyol. Assoc. Bull. 4, 122 p.

Bayless, J.D. 1964. Tall tales. Wildl. N.C. 28(5):4-6.

Bayless, J.D. 1968. Striped bass hatching and hybridization experiments. Proc. Annu. Conf. Southeast Assoc. Game Fish Comm. 21(1967):233-244.

Bayless, J.D. 1972. Artificial propagation and hybridization of striped bass, Morone saxatilis (Walbaum). S.C. Wildl. Mar. Res. Dep., 135 p.

Bean, T.H. 1883. Notes of fishes observed at the head of Chesapeake Bay in the spring of 1882; and upon other species of the same region. Proceedings, United States National Museum, Vol. VI, 1883, pp. 365-367. Washington.

Beck, A.P., G.V. Poje, and W.T. Walker. 1975. A laboratory study on the effects of the exposure of some entrainable Hudson River biota to hydrostatic pressure regimes calculated for the proposed Cornwall pumped-storage plant, pp. 167-204. In S.B. Saila (ed.), Fisheries and energy production: A symposium. Lexington Books, Lexington, MA.

Belding, D.L. 1921. A report upon the alewife fisheries of Massachusetts. MA. Dept. Nat. Res., Div. Mar. Fish., Contrib. 11, Boston, 135 p.

Benville, P.F., Jr. and S. Korn. 1977. The acute toxicity of six monocyclic aromatic crude oil components to striped bass (Morone saxatilis) and bay shrimp (Crago franciscorum). Calif. Fish Game 63(4):204-209.

Berry, F.H. 1964. Review and emendation of: family Clupeidae. Copeia 1964(4):720-730.

Beverton, R.J.H. and S.J. Holt. 1959. A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics, pp. 142-180. In Ciba Foundation Colloquium on Ageing. 5. The lifespan of animals. A. Churchill Ltd., London.

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv., Fish. Bull. 53(74):577 p.

Blair, A.B. 1977. American shad culture and distribution studies at Harrison Lake National Fish Hatchery. In Proc. Workshop on American shad. U.S. Fish Wildl. Serv. and NMFS, Amherst, MA., Dec. 1976, 10 p.

Bonn, E.W., W.M. Balley, J.D. Bayless, K.E. Erickson, and R.E. Stevens (ed.). 1976. Guidelines for striped bass culture. American Fisheries Society, Striped Bass Committee of the Southern Division, 103 p.

Bouck, G.R., G.A. Chapman, P.W. Schneider, Jr., and D. G. Stevens. 1976. Observations on gas bubble disease among wild adult Columbia River fishes. Trans. Am. Fish. Soc. 105:114-115.

Bowles, R.R. 1976. Effects of water velocity on activity patterns of juvenile striped bass. Proc. 29th Annu. Conf. Southeast. Assoc. Game Fish Comm. 1975:142-151.

Boynton, W.R., T.T. Polgar, and H.H. Zion. 1981. Importance of juvenile striped bass food habits in the Potomac Estuary. Trans. Am. Fish. Soc. 110:56-63.

Boynton, W.R., E.M. Setzler, K.V. Wood, H.H. Zion, and M. Homer. 1977. Draft report on Potomac River fisheries study; ichthyoplankton and juvenile investigations. Univ. Md. CEES Ref. No. 77-169 - [illegible]

Braid, M.R. 1977. Factors affecting the survival and growth of striped bass, Morone saxatilis (Walbaum), fry in recirculating systems. Ph.D. Dissertation, Auburn Univ., 86 p.

Brockson, R.W. and H.T. Bailey. 1973. Respiratory response of juvenile chinook salmon and striped bass exposed to benzene, a water-soluble component of crude oil, pp. 783-791. In Proceedings of a joint conference on prevention and control of oil spills (Am. Pet. Inst., Environ. Prot. Agency, U.S. Coast Guard, Wash., D.C.)

Brown, B.E. 1965. Meristic counts of striped bass from Alabama. Trans. Am. [illegible]

Brown, B.E. 1969. Differential sex mortality associated with handling landlocked alewives. Trans. Am. Fish. Soc. 90(1):80-81.

Bulak, J.S. and T.A. Curtis. 1978. Santee Cooper Rediversion Project, Ann. Prog. Rep., Proj. SCR 1-2. S.C. Wildl. Mar. Res. Dept., Div. Wildl. Freshwater Fish., 79 p.

Bulak, J.S., J.S. Tuten, and T.A. Curtis. 1979. Santee-Cooper [illegible] Proj. [illegible], 1 Jan. 1979 to 30 Sept. 1979. S.C. Wildl. Mar. Res. Dept., Div. Wildl. Freshwater Fish., 116 p.

Burbidge, R.G. 1974. Distribution, growth, selective feeding, and energy transformations of young-of-the-year blueback herring, Alosa aestivalis (Mitchell), in the James River, Virginia. Trans. [illegible]

Burns, F. 1887. Rockfish in South Carolina. Bull. U.S. Fish Comm. (1886)6:124

Cable, L.E. 1944. Shad. In G.R. Lunz, Jr., Special study of the marine fishery resources of South Carolina. Bull. 14:14-20. S.C. State Planning Board, Columbia, S.C.

Cadieu, C.R. and J.D. Bayless. 1968. Anadromous fish survey of the Santee and Cooper Rivers South Carolina. S.C. Wildl. Mar. Res. Dept. Job Compl. Rep. AFS-2-1, 92 p.

Calhoun, A.J., C.A. Woodhull, and W.C. Johnson. 1950. Striped bass reproduction in the Sacramento River system in 1948. Calif. Fish Game 36:135-145.

Carolina Power and Light Company. 1979. Impingement studies the Brunswick Steam Electric Plan, Southport, North Carolina, 1974-1978. Carolina Power and Light Co., Raleigh, N.C., 141 p.+ Appendix.

Carscadden, J.E. 1975. Studies on the American shad (Alosa sapidissima, Wilson) in the St. John River and Miramichi River, New Brunswick with special reference to homing and R-K selection. Ph.D. Dissertation, McGill Univ.

Carscadden, J.E. and W.C. Leggett. 1975a. Meristic differences in spawning populations of American shad, Alosa sapidissima: evidence for homing to tributaries in the St. John River, New Brunswick. J. Fish. Res. Board Can. 32:653-660.

Carscadden, J.E. and W.C. Leggett. 1975b. Life history variations in populations of American shad, Alosa sapidissima (Wilson), spawning in tributaries of the St. John River, New Brunswick. J. Fish Biol. 7(5):595-609.

Chadwick, H.K. 1960. Toxicity of tricon oil spill eradicator to striped bass (Roccus saxatilis). Calif. Fish Game 46:371-372.

Cheek, R.P. 1966. Biological studies to determine the possible effect on American shad fishery of the proposed water developments in the Upper St. Johns River, Florida. Progress Rep. AFS-2 (Mimeo, 6 p.).

Cheek, R.P. 1968. The American shad. U.S. Fish Wildl. Serv., Fish. Leafl. 614, 13 p.

Chestnut, A.F. and H.S. Davis. 1975. Synopsis of marine fisheries of North Carolina, Part I. Univ. of North Carolina Sea Grant Program, Pub. No. UNC-SG-75-12, 425 p.

Chipman, R.K. 1956. Progress report on the striped bass investigations in Louisiana. Mimeo Rep., 9 p.

Chittenden, M.E., Jr. 1969. Life history and ecology of the American shad, Alosa sapidissima, in the Delaware River. Ph.D. Thesis. Rutgers University, 458 p.

Chittenden, M.E., Jr. 1971. Effects of handling and salinity on oxygen requirements of the striped bass, Morone saxatilis. J. Fish. Res. Board Can. 28:1823-1830.

Chittenden, M.E., Jr. 1972a. Salinity tolerance of young blueback herring, Alosa aestivalis. Trans. Am. Fish. Soc. 101:123-125.

Chittenden, M.E., Jr. 1972b. Reponses of young American shad, Alosa sapidissima, to low temperatures. Trans. Am. Fish. Soc. 101:680-685.

Chittenden, M.E., Jr. 1973. Effects of handling on oxygen requirements of American shad (Alosa sapidissima). J. Fish. Res. Board Can. 30:105-110.

Chittenden, M.E., Jr. 1974. Trends in the abundance of young American shad, Alosa sapidissima, in the Delaware River basin. Chesapeake Sci. 15:96-103.

Chittenden, M.E., Jr. 1975. Dynamics of American shad, Alosa sapidissima, runs in the Delaware River. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 73:487-493.

Chittenden, M.E., Jr. 1976a. Present and historical spawning grounds and nurseries of American shad, Alosa sapidissima, in the Delaware River. NOAA Fish. Bull. 74:343-352.

Chittenden, M.E., Jr. 1976b. Weight loss, mortality, feeding, and duration of residence of adult American shad, Alosa sapidissima, in freshwater. NOAA Fish. Bull. 74:151-157.

Chittenden, M.E. and J.R. Westman. 1967. Highlights of the life history of the American shad in the Delaware River. Rutgers, the State Univ., New Brunswick, N.J. Mimeo.

Christie, R.W. 1978. Spawning distribution of blueback herring Alosa aestivalis (Mitchell), in abandoned rice fields and tributaries of the West Branch of Cooper River, South Carolina. M.S. Thesis, Clemson Univ., 57 p.

Cianci, J.M. 1969. Larval development of the alewife, Alosa pseudoharengus Wilson, and the glut herring, Alosa aestivalis Mitchell. M.S. Thesis. University of Connecticut, 62 p.

Clark, G.H. 1968. Weight and age determination of striped bass. Calif. Fish Game. 24:175-177.

Cooper, R.A. 1961. Early life history and spawning migration of the alewife, Alosa pseudoharengus. M.S. Thesis. University of Rhode Island, 58 p.

Coutant, C.C. and R.J. Kedl. 1975. Survival of larval striped bass exposed to fluid-induced and thermal stresses in a simulated condenser tube. Oak Ridge Nat. Lab., Environ. Sci. Div., Publ. 637, 37 p.

Crance, J.H. 1971. Description of Alabama estuarine areas-cooperative Gulf of Mexico inventory. Ala. Dept. Cons., Ala. Mar. Res. Bull. 5, 85 p.

Crateau, E.J., P. Moon, and C.M. Wooley. 1980. Apalachicola River striped bass project. Ann. Progr. Rept., FY 1980, Jacksonville Area. U.S. Fish Wildl. Serv., Fish. Res. Proj., Panama City, Florida, 58 p.

Crochet, D.W. 1974. Commercial anadromous fishery Waccamaw and Pee Dee Rivers. Ann. Prog. Rep., 1 Oct. 1973-30 June 1974. S.C. Wildl. Mar. Res. Dept., Div. Game Freshwater Fish.

Crochet, D.W. 1975. Commercial anadromous fishery Waccamaw and Pee Dee Rivers. Ann. Prog. Rep., AFC-5-2, 1 July 1974-30 June 1975. SC. Wildl. Mar. Res. Dept., 39 p.

Crochet, D.W., D.E. Allen, and M.L. Hornberger. 1976. Commercial anadromous fishery Waccamaw and Pee Dee Rivers. Job Compl. Rep. 1 Oct. 1973-30 Dec. 1976. S.C. Wildl. Mar. Res. Dept., Div. Game Freshwater Fish., 113 p.

Crochet, D.W., D.E. Allen, and M.L. Hornberger. 1977. Evaluation of commercial fisheries for American shad in South Carolina and status of the species in selected waters, p. 4. In Proc. Workshop on American Shad. U.S. Fish Wildl. Serv. and NMFS, Amherst, MA., Dec. 1976.

Curtis, T.A. 1974. Anadromous fish survey of the Santee and Cooper River system. Ann. Prog. Rep. Proj. AFS-3-4, 1 July 1973-30 June 1974, S.C. Wildl. Mar. Res. Dept., Div. Game Freshwater Fish., 54 p.

Curtis, T.A. 1975. Anadromous fish survey of the Santee and Cooper River System. Ann. Progr. Rep. Proj. AFS-3-5. S.C. Wildl. Mar. Res. Dept., Div. Game Freshwater Fish.

Curtis, T.A. 1976. Anadromous fish survey of the Santee and Cooper river system. Ann Prog. Rep. AFS-3-6. S.C. Wildl. Mar. Res. Dept., Div. Game Freshwater Fish.

Curtis, T.A. 1977. Anadromous fish survey of the Santee and Cooper River System. Ann. Prog. Rep. AFS-3-7 for period 1 July 1976 through 30 June 1977. S.C. Wildl. Mar. Res. Dept., Div. Wildl. Freshwater Fish., 27 p.

Curtis, T.A. 1978. Anadromous fish survey of the Santee and Cooper River System. Ann. Prog. Rep. AFS-3-8. S.C. Wildl. Mar. Res. Dept., Div. Wildl. Freshwater Fish.

Dadswell, M.J. 1979. Biology and population characteristics of the shortnose sturgeon, Acipenser brevirostrum LeSueur 1818 (Osteichthyes: Acipenseridae) in the Saint John River Estuary, New Brunswick, Canada. Can. J. Zool. 57(11):2186-2210.

Davies, W.D. 1970. The effect of temperature, pH and total dissolved solids on the survival of immature striped bass, Morone saxatilis (Walbaum). Ph.D. Thesis, N.C. State Univ., Raleigh, 100 p.

Davis, J. 1973. Spawning sites and nurseries of fishes of the genus Alosa in Virginia. Proc. Workshop on Egg, Larval and Juvenile Stages of Fish in Altantic Coast Estuaries, NOAA Tech. Publ. No. 1, pp. 140-141.

Davis, J.R. and R.P. Cheek. 1966. Distribution, food habits, and growth of young clupeids, Cape Fear River system, North Carolina. Proc. 20th Ann. Conf. Southeast Assoc. Game Comm., pp. 250-260.

Davis, J.T., B.J. Fontenot, C.E. Hoenke, A.M. Williams, and J.S. Hughes. 1970. Ecological factors affecting anadromous fishes of Lake Pontchartrain and its tributaries. La. Wildl. Fish. Comm., Fish. Bull. No. 9, 63 p.

Dawson, M.A., E. Gould, F.P. Thurberg, and A. Calabrese. 1977. Physiological response of juvenile striped bass, Morone saxatilis, to low levels of cadmium and mercury. Chesapeake Sci. 18(4):353-359.

Dean, Jim. 1969. Carolina shad comeback. Field and Stream 83(12): 58-59, 126, 128, 130, 132.

DeArmon, I.A., Jr. 1948. Sampling techniques on the ovary of the striped bass, Roccus saxatilis (Walbaum). M.S. Thesis, Virginia Polytechnic Inst., Blacksburg, 40 p.

Dees, L.T. 1961. Sturgeons. U.S. Fish and Wildl. Serv., Fish Leafl. 526, 8 p.

Dodson, J.J., W.C. Leggett, and R.A. Jones. 1972. The behavior of adult American shad (Alosa sapidissima) during migration from salt to freshwater as observed by ultrasonic tracking techniques. J. Fish. Res. Board Can. 29:1445-1449.

Dominy, C.L. 1971. Evaluation of a pool and weir fishery for passage of alewives (Alosa pseudoharengus) at White Rock, Gaspereau River, Nova Scotia. Dept. of Fish. & Forestry Canada, Res. Develop. Branch, Halifax, N.S., Prog. Rep. 3, 22 p.

Dominy, C.L. and G.L. Myatt. 1973. Short-term effects of three different marks on the recapture and survival of the alewife, Alosa pseudoharengus. Trans. Am. Fish. Soc. 102:633-637.

Dorfman, D. 1974. Reponses of striped bass to temperature gradients. Underwater Nat. 8(1):42-43.

Dorfman, D. and J. Westman. 1970. Responses of some anadromus fishes to varied oxygen concentrations and increased temperatures. Rutgers Univ., Water Resources Res. Inst., Partial completion and termination report, 75 p.

Doroshev, S.I. 1970. Biological features of the eggs, larvae and young of the striped bass (Roccus saxatilis (Walbaum)) in connection with the problem of its acclimatization in the U.S.S.R. J. Ichthyol. (Engl. transl. Vopr. Ikhtiol.) 10(2):235-248.

Dudley, R.G., A.W. Mullis, and J.W. Terrell. 1977. Movements of adult striped bass (Morone saxatilis) in the Savannah River, Georgia. Trans. Am. Fish. Soc., 106:314-322.

Edsall, T.A. 1964. Feeding by three species of fishes on the eggs of spawning alewives. Copeia 1964(1):226-227.

Edsall, T.A. 1970. The effects of temperature on the rate of development and survival of alewife eggs and larvae. Trans. Am. Fish. Soc. 99:376-380.

Evermann, B.W. and B.A. Bean. 1898. Indian River and its fishes. Rep. U.S. Comm. Fish. 1896:227-248.

Fischer, C.A. 1980. Anadromous Fisheries Research Program. Cape Fear River System, Phase II. N.C. Dep. Nat. Res. Comm. Develop., Div. Mar. Fish., Completion Report for Proj. AFCS-15, 65 p.

Fish, E.F. and E.G. McCoy. 1969. The river discharges required for effective spawning by striped bass in the rapids of the Roanoke River of North Carolina. N.C. Wildl. Res. Comm., Raleigh, 38 p.

Frankensteen, E.D. 1976. Genus Alosa in a channelized and unchannelized creek of the Tar River Basin, North Carolina. M.A. Thesis, East Carolina Univ., Greenville, 123 p.

Fredin, R.A. 1954. Causes of fluctuations in abundance of Connecticut River shad. U.S. Fish. Wildl. Serv. Fish. Bull. 54:247-259.

Friedersdorff, J.W. 1977. Population estimates and relative abundance work on adult American shad stocks in the Delaware River (1969-1976), pp. 83-106. In Proc. Workshop on American shad, 14-16 Dec. 1976, Amherst, MA.

Gabriel, W.L., W.C. Leggett, J.E. Carscadden, and B.D. Glebe. 1976. Origin and characteristics of "fall-run" American shad (Alosa sapidissima) from the St. John River, New Brunswick. J. Fish. Res. Board Can. 33:1764-1770.

Geddings, W.R. 1973. Annual progress report. Anadromous Fish Project AFS-9-3, 1 July 1972-30 June 1973. Ga. Dept. Nat. Res., Game Fish Div., Atlanta, mimeo.

Glebe, B.D. 1977. Weight loss and associated energy expenditure of American shad (Alosa sapidissima, Wilson) during the freshwater spawning migration. Ph.D. Dissertation, McGill Univ.

Godwin, W.F. 1968. The shad fishery of the Altamaha River, Georgia. Ga. Game Fish. Comm., Mar. Fish. Div. Contrib. Ser. 8, 39 p.

Godwin, W.F. and J.G. Adams. 1969. Young clupeids of the Altamaha River, Georgia. Ga. Game Fish. Comm., Mar. Fish. Div. Contrib. Ser. 15, 30 p.

Godwin, W.F. and L.G. McBay. 1967. Preliminary studies of the shad fishery of the Altamaha River, Georgia. Ga. Game Fish. Comm., Mar. Fish. Div. Contrib. 2, Proj. AFC-1-1, 28 p.

Gowanloch, J.H. 1933. Fishes and fishing in Louisiana. Bull. La. Conserv. Dept. 23:208-213.

Greeley, J.R. 1937. Fishes of the area with annotated list, pp. 45-103. In a biological survey of the lower Hudson watershed. Suppl. 26th Annu. Rep., N.Y. Conserv. Dept. (1936), Biol. Surv. 11, Albany, N.Y.

Gudger, E.W. 1929. Voracity of fish. Nat. Hist. 29:651-655.

Haley, R., S.P. Davis, and J.M. Hyde. 1967. Environmental stress and Aeromonas liquefaciens in American and threadfin shad mortalities. Progr. Fish-Cult. 29(4):193.

Hall, C.S. 1971. Annual Progress Report-Anadromous Fish Project, AFS-9-1, 1 July 1970-30 June 1971. Ga. Dept. Nat. Res., Game Fish Div., mimeo.

Hardy, J.D., Jr. 1978. Development of fishes of the Mid-Atlantic Bight: An atlas of the egg, larval and juvenile stages. Vol. III. Aphredoderidae through Rachycentridae. U.S. Fish Wildl. Serv., Biol. Serv. Prog. FWS/OBS-78/12, 394 p.

Harper, J.L. and R. Jarman. 1972. Investigations of striped bass, Roccus saxatilis (Walbaum), culture in Oklahoma. Proc. 25th Ann. Conf. Southeast. Assoc. Game Fish Comm. 1971:510-512.

Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Can., Bull. 180, 740 p.

Hassler, W.W. and N.L. Hill. 1981. The status and abundance of striped bass in the Roanoke River and Albemarle Sound, North Carolina, 1956-1980. Ann. Mimeo Rep; Zoology Dept., North Carolina State University, Raleigh, N.C., 155 p.

Hassler, W.W., W.T. Hogarth, and H.L. Liner III. 1967. The status and abundance of the striped bass in Roanoke River North Carolina for 1966. Mimeo. Rep. to the N.C. Dept. Conserv. and Develop., Div. Comm. Sport Fish., Raleigh, N.C., 53 p.

Hassler, W.W., W.L. Trent, and B.M. Florence. 1966. The status and abundance of the striped bass in the Roanoke River, North Carolina, for 1965. Mimeo Rep. to N.C. Dept. Conserv. and Develop., Div. Comm. Sport Fish., Raleigh, N.C., 52 p.

Havey, K.A. 1973. Production of juvenile alewives, Alosa pseudoharengus, at Love Lake, Washington County, Maine. Trans. Am. Fish. Soc. 102:434-437.

Hawkins, J.H. 1979. Anadromous Fisheries Research Program-Neuse River. Progress Rep. for Proj. AFCS-13-2. N.C. Dept. Nat. Res. Comm. Develop., Div. Mar. Fish., 103 p.

Hazel, C.R., W. Thomsen, and S.J. Meith. 1971. Sensitivity of striped bass and stickleback to ammonia in relation to temperature and salinity. Calif. Fish Game 57:138-153.

Heinle, D.R. 1976. Conditions affecting rockfish abundance studied by C.B.I., Dept. Nat. Res. Md., Comm. Fish News 9(4).

Hildebrand, S.F. 1963. Family Clupeidae, pp. 257-385, 397-442. In Fishes of the western North Atlantic. Sears Found. Mar. Res., Mem. 1(3).

Hildebrand, S.F. and W.C. Schroeder. 1928. Fishes of Chesapeake Bay. U.S. Bur. Fish., Bull. 43 (Pt. 1)., 366 p.

Hill, D.R. 1959. Some uses of statistical analysis in classifying races of American shad (Alosa sapidissima). U.S. Fish Wildl. Serv., Fish. Bull. 59(147):269-286.

Hoff, J.G. 1965. Two shortnose sturgeon, Acipenser brevirostris, from the Delaware River, Scudder's Falls, New Jersey. Bull. N.J. Acad. Sci. 10:23.

Hoff, J.G. 1979. Annotated bibliography and subject index on the shortnose sturgeon, Acipenser brevirostrum. NOAA Tech. Rep. 731, 16 p.

Holder, D.R. and C.S. Hall. 1975. Recruitment of hatchery-reared striped bass fingerlings in a native river population. Ga. Dept. Nat. Res., Game Fish Div., Final Rep. Fed. Aid Project AFS-9.

Holland, B.F., Jr. and S.G. Keefe. 1977. Anadromous fisheries research program, northern coastal area. Compl. Rep. Proj. AFCS-9. N.C. Div. Mar. Fish, 27 p.

Holland, B.F., Jr. and G.F. Yelverton. 1973. Distribution and biological studies of anadromous fishes offshore North Carolina. N.C. Dept. Nat. Econ. Res. Spec. Sci. Rep. 24, 132 p.

Holland, B.F., Jr., A.B. Powell, and G.F. Yelverton. 1975. Anadromous fisheries research program, Northern Coastal Region, Offshore N.C. Ann. Prog. Rep. AFCS-8-2, N.C. Dept. Nat. Res. Comm. Develop., Div. Mar. Fish, 89 p.

Hollis, E.H. 1948. The homing tendency of shad. Science 108(2804):332-333.

Hollis, E.H. 1967. An investigation of striped bass in Maryland. A final report. Fed. Aid in Fish Restoration F-3-R, Dept. Chesapeake Bay Affairs, 56 p.

Hornsby, J.H. and C.S. Hall. 1981. Impact of supplemental stocking of striped bass fingerlings in the Ogeechee River. Ga. Dept. Nat. Res., Game Fish Div. Final Rep. AFS-11, 62 p.

Horseman, L.O. and R.J. Kernehan. 1976. An indexed bibliography of the striped bass, Morone saxatilis, 1670-1976. Ichthyol. Assoc. Bull. No. 13, 118 p.

Huff, J.A. 1975. Life history of Gulf of Mexico sturgeon, Acipenser oxyrhynchus desotoi, in Suwannee River, Florida. Fla. Mar. Res. Publ. 16, 32 p.

Huish, M.T. and J.P. Geaghan. 1979. A study of adult and juvenile fishes of the lower Cape Fear River near the Brunswick Steam Electric Plant 1975-1976. Report 79-4 to Carolina Power and Light Company, Raleigh, N.C., 148 p.

Humphries, E.T. 1966. Spawning grounds of the striped bass, Roccus saxatilis (Walbaum), in the Tar River, North Carolina. M.S. Thesis, East Carolina Univ., Greenville, 50 p.

Jackson, H.W. and R.E. Tiller. 1952. Preliminary observations on [illegible]ning potential in the striped bass (Roccus saxatilis) (Walbaum). Md. Dept. Res. and Educ. Publ. No. 93:1-16.

Jessop, B.M. 1973. Marking alewife fry with biological stains. Progr. Fish-Cult. 35(2):90-93.

Johnson, H.B. and W.W. Hassler. 1980. Cooperative management [illegible]le Sound-Roanoke River striped bass. Ann. [illegible] AFS-14-3. N.C. Dept. Nat. Res. Comm. Develop., Div. Mar. Fish., 21 p. (mimeo).

Johnson, H.B., B.F. Holland, Jr., and S.G. Keefe. 1977. Anadromous fisheries research program, northern coastal area. N.C. Div. Mar. Fish., Compl . Rep., Proj. AFCS-11, 97 + 40 p.

Johnson, H.B., D.W. Crocker, B.F. Holland, Jr., J.W. Gilliken, D.L. Taylor, M.W. Street, J.G. Loesch, W.H. Kriete, Jr., [illegible] 1978. Biology and management of mid-Atlantic anadromous fishes under extended jurisdiction. NC-VA AFCS 9-2. N.C. Div. of Marine Fish. and VIMS, 175 p.

Johnson, S.K. and W.A. Rogers. 1972. Ergasilus clupeidarum sp. n. (Copepoda:Cyclopoida) from clupeid fishes of the southeastern U.S. with a synopsis of the North American Egasilus species with a two-jointed first endopod. J. Parasit. 58(2):385-392.

Jones, P.W., F.D. Martin, and J.D. Hardy, Jr. 1978. Development of fishes of the mid-Atlantic bight: an atlas of the egg, larval and juvenile stages. Vol I. Acipenseridae through [illegible]uridae. U.S. Fish Wildl. Serv., Biol. Serv. Progr. FWS/OBS-78/12, 3[illegible]

Jones, R.A., P. Minta and V. Crecco. 1977. A review of American [illegible]cticut River, pp. 135-162. In [illegible] workshop on American shad, 14-16 Dec. 1976, [illegible]

Jordan, D.S. and B.W. Evermann. 1896. The fishes of North and [illegible]cription catalogue of the species of [illegible] vertebrates found in the waters of North America, [illegible]anama. U.S. Natl. Mus. Bull. 47, [illegible]

Judy, M.H. 1960. Validity of age determination from scales of [illegible]d. U.S. Fish Wildl. Serv., Fish. Bull. [illegible]

Katz, H.M. 1978. Circadian rhythms in juvenile American shad, Alosa sapidissima. J. Fish Biol. 12(6):609-614.

Kerr, J.E. 1953. Studies on fish preservation at the Contra Costa Steam Plant of the Pacific Gas and Electric Company. Calif. Dept. Fish Game, Fish Bull. 92, 66 p.

Kilby, J.D., E. Crittenden, and L.E. Williams. 1959. Ichthyological notes: Several fishes new to Florida freshwaters. Copeia 1959: 77-78.

Kissil, G.W. 1969. Contributions to the life history of the alewife, Alosa pseudoharengus (Wilson), in Connecticut. Ph.D. Thesis, University of Connecticut, 111 p.

Kissil, G.W. 1974. Spawning of the anadromous alewife, Alosa pseudoharengus (Wilson), in Bride Lake, Connecticut. Trans. Am. Fish. Soc. 103:312-317.

Klyashtorin, L.B. and A.A. Yarzhombeck. 1975. Some aspects of the physiology of the striped bass, Morone saxatilis. J. Ichthyol. 15:985-989.

Koo, T.S.Y. and M.L. Johnston. 1978. Larva deformity in striped bass, Morone saxatilis (Walbaum), and blueback herring, Alosa aestivalis (Mitchell), due to the heat shock treatment of developing eggs. Environ. Pollut. 16(2):137-149.

Koo, T.S.Y. and D.E. Ritchie, Jr. 1973. Growth of juvenile striped bass, Morone saxatilis, as determined by tagging and recapture. In A.L. Pacheco (ed.), Proceedings of a workshop on egg, larval and juvenile stages of fish in the Atlantic Coast Estuaries, p. 124-125. U.S. Dept. Commerce., NOAA, NMFS, Middle Atl. Coastal Fish. Cent., Tech. Publ. No. 1, 338 p.

Koo, T.S.Y. and J.S. Wilson. 1972. Sonic tracking striped bass in the Chesapeake and Delaware Canal. Trans. Am. Fish. Soc. 101:453-462.

Korn, S., J.W. Struhsaker, and P. Benville, Jr. 1976. Effects of benzene on growth, fat content, and caloric content of striped bass, Morone saxatilis. NOAA Fish. Bull. 74:694-698.

Kruger, R.L. and R.W. Brocksen. 1978. Respiratory metabolism of striped bass, Morone saxatilis (Walbaum), in relation to temperature. J. Exp. Mar. Biol. Ecol. 31(1):55-66.

Lal, K., R. Lasker, and A. Kuljis. 1977. Acclimation and rearing of striped bass larvae in sea water. Calif. Fish Game 63(4):210-218.

LaPointe, D.F. 1958. Age and growth of the American shad from three Atlantic coast rivers. Trans. Am. Fish. Soc. 87:139-150.

Laurence, G.C. and R.W. Yerger. 1967. Life history studies of the Alabama shad, Alosa alabamae, in the Apalachicola River, Florida. Proc. 20th Annu. Conf. Southeast Assoc. Game Fish Comm., pp. 260-273.

Leach, G.C. 1925a. Propagation and distribution of food fishes, fiscal year 1924. U.S. Comm. Fish. Rep. (1924):361-440.

Leach, G.C. 1925b. Artificial propagation of shad. U.S. Comm. Fish. (1924):459-486.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. 1980 et seq. Atlas of North American Freshwater Fishes. N.C. State Mus. Nat. Hist., Raleigh i-x + 854 p.

Leggett, W.C.G. 1969. Studies on the reproductive biology of the American shad, Alosa sapidissima, Wilson. A comparison of populations from four rivers of the Atlantic seaboard. Ph.D. Thesis. McGill Univ., Montreal, 125 p.

Leggett, W.C. 1972. Weight loss in American shad (Alosa sapidissima, Wilson) during the freshwater migration. Trans. Am. Fish. Soc. 101:549-552.

Leggett, W.C. 1973. The migrations of the shad. Scientific American 228(3):92-98.

Leggett, W.C. and R.A. Jones. 1971. Net avoidance behavior in American shad (Alosa sapidissima) as observed by ultrasonic tracking techniques. J. Fish. Res. Board Can. 28:1167-1171.

Leggett, W.C. and R.N. O'Boyle. 1976. Osmotic stress and mortality in adult American shad during transfer from saltwater to freshwater. J. Fish. Biol. 8(6):459-469.

Leggett, W.C.G. and R.R. Whitney. 1972. Water temperature and the migrations of American shad. U.S. Natl. Mar. Fish Serv. Fish. Bull. 70:659-670.

Lehman, B.A. 1953. Fecundity of Hudson River shad. U.S. Fish Wildl. Serv., Res. Rep. 33, 8 p.

Leim, A.H. 1924. The life history of the shad (Alosa sapidissima (Wilson)) with special reference to the factors limiting its abundance. Contrib. Canad. Biol., n.s., 2(11):161-284.

Leim, A.H. and W.B. Scott. 1966. Fishes of the Atlantic coast of Canada. Fish. Res. Board Can. Bull. 155, 485 p.

Leland, J.G., II. 1968. A survey of the sturgeon fishery of South Carolina. Contrib. Bears Bluff Lab. 47:3-27.

LeSueur, C.A. 1818. Description of several species of Chondropterygious fishes of North America, with their varieties. Trans. Am. Philos. Soc. 1:383-395.

Levesque, R.C. and R.J. Reed. 1972. Food availability and consumption by young Connecticut River shad Alosa sapidissima. J. Fish. Res. Board Can. 29:1495-1499.

Lewis, R.M. and R.R. Bonner, Jr. 1966. Fecundity of the striped bass, Roccus saxatilis (Walbaum). Trans. Am. Fish. Soc. 95:328-331.

Libey, G.S. 1976. A mathematical model and computer simulation of the anadromous alewife, Alosa pseudoharengus (Wilson), migration in the Parker River, Massachusetts. Ph.D. Dissertation, Univ. Mass., 206 p.

Linton, E. 1901. Parasites of fishes of the Woods Hole region. Bull. U.S. Fish. Comm. 19(1899):405-492.

Lippson, A.J. and R.L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River estuary. Prepared for the Power Plan Siting Program of the Maryland Dept. Nat. Res., PPSP-MP-13, 282 p.

Livingston, R.J., R.L. Iverson, R.H. Estabrook, V.E. Keys, and J. Taylor, Jr. 1974. Major features of the Apalachicola Bay System: Physiography, biota and resource management. Florida Scientist 37(4):245-271.

Loeber, T.S. 1951. A report of an investigation of the temperature and salinity relationships of striped bass and salmon in connection with the Reber plan. Calif. Dept. Fish Game, Inland Fish. Br., Rept. Bur. Fish. Conserv., 40 p.

Loesch, J. 1969. A study of the blueback herring, Alosa aestivalis (Mitchell), in Connecticut waters. Ph.D. Thesis. University of Connecticut, 78 p.

Loesch, J.G. and W.A. Lund, Jr. 1977. A contribution to the life history of the blueback herring, Alosa aestivalis. Trans. Am. Fish. Soc. 106:583-589.

Loesch, J.G., W.H. Kriete, Jr., H.B. Johnson, B.F. Holland, and M.W. Street. 1977. Biology and management of mid-Atlantic anadromous fishes under extended jurisdiction. Proj. NU. NC-VA AFCS 9-1, Proj. Report 1977, 183 p.

Logan, H.J. 1968. Comparison of growth and survival rates of striped bass and striped bass x white bass hybrids under controlled environments. Proc. Annu. Conf. Southeast Assoc. Fish Game Comm. 21(1967):260-263.

Magnin, E. 1964. Croissance en longueur de trois esturgeons d'Amerique du Nord: Acipenser oxyrhynchus Mitchell, Acipenser fulvescens Rafinesque et Acipenser brevirostrum LeSueur. Verh. Int. Ver. Limnol. 15:968-974.

Magnin, E. and G. Beaulieu. 1960. Deplacements des esturgeons (Acipenser fulvescens et A. oxyrhynchus) du fleuve Saint-Laurent d'apres les donnes due marquage. Nat. CAnad. (Que.). 87(11):237-252.

Mailvan, R.A. and A.P. Alekperov. 1976. An experimental study on the growth and development of sturgeons (Family Acipenseridae). J. Ichthyol. 16(2):343-347.

Manea, G. 1970. Productia si Rezervele de Sturioni de pa Glob (Production and stocks of sturgeon throughout the world). Buletinul de Cercetari Piscicole 29(4):52-65.

Manooch, C.S., III. 1973. Food habits of yearling and adult striped bass, Morone saxatilis (Walbaum), from Albemarle Sound, North Carolina. Chesapeake Sci. 14:73-86.

Mansueti, A.J. and J.D. Hardy, Jr. 1967. Development of fishes of the Chesapeake Bay Region, an atlas of egg, larval, and juvenile stages, Part I. Nat. Res. Inst., Univ. Maryland, 202 p.

Mansueti, R. 1956. Hickory shad eggs and larvae reared successfully in lab. Md. Tidewater News, Vol 13, No. 1, pp. 1 and 3.

Mansueti, R.J. 1958. Eggs, larvae and young of the striped bass, Roccus saxatilis. Chesapeake Biol. Lab. Contrib. 112, 35 p.

Mansueti, R.J. 1962. Eggs, larvae, and young of the hickory shad, Alosa mediocris, with comments on its ecology in the estuary. Chesapeake Sci. 3(3):173-205.

Mansueti, R.J. and E.H. Hollis. 1963. Striped bass in Maryland tidewater. Univ. Md., Nat. Res. Inst., Educ. Ser. 61, 28 p.

Mansueti, R.J. and H. Kolb. 1953. A historical review of the shad fisheries of North America. Md. Dep. Res. Educ. Publ. 97, 292 p.

Marcy, B.C. 1969. Age determination from scales of Alosa pseudoharengus (Wilson) and Alosa aestivalis (Mitchell) in Connecticut waters. Trans. Am. Fish. Soc. 98:622-630.

Marcy, B.C., Jr. and P.M. Jacobson. 1976. Early life history studies of American shad in the lower Connecticut River and the effects of the Connecticut Yankee Plant. Am. Fish. Soc., Monogr. 1, 252 p.

Marcy, B.C., Jr., P.M. Jacobson, and R.L. Nankee. 1972. Observations on the reactions of young American shad to a heated effluent. Trans. Am. Fish. Soc. 101:740-743.

Markle, D.F. and G.C. Grant. 1970. The summer food habits of young-of-the-year striped bass in three Virginia rivers. Chesapeake Sci. 11:50-54.

Marshall, M.D. 1976. Anadromous fisheries research program Tar River, Pamlico River, and Northern Pamlico Sound. Compl. Rep. for Proj. AFCS-10. N.C. Dept. Nat. Econ. Res., Div. Mar. Fish., 90 p.

Marshall, M.D. 1977. Anadromous fisheries research program - Neuse River. Prog. Rep. for Proj. AFCS-13-1, N.C. Dept. Nat. Res. Comm. Develop., Div. Mar. Fish., 70 p.

Massmann, W.H. 1951. Characteristics of spawning areas of shad, Alosa sapidissima (Wilson), in some Virginia streams. Trans. Am. Fish. Soc. 81:78-93.

Massman, W.H. 1963. Summer food of juvenile American shad in Virginia waters. Chesapeake Sci. 4:167-171.

May, O.D., Jr. and J.C. Fuller, Jr. 1962. A study on striped bass egg production in the Congaree and Wateree Rivers. S.C. Wildl. Res. Dept., Div. Game, 28 p.

May, O.D., Jr. and J.C. Fuller, Jr. 1965. A study of striped bass egg production in the Congaree and Wateree Rivers. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 16(1962):285-301.

McAllister, D.E. 1970. Rare or endangered Canadian fishes. Can. Field-Nat. 84:5-8.

McBay, L.G. 1968. Location of sexually mature striped bass. Ga. Game Fish Comm., Coastal Reg. Fish Invest., Rep. Fiscal Yr. 1968. Job II-1:27-48.

McBay, L.G. 1970. A preliminary report on fry production and rearing of fingerling striped bass Morone saxatilis (Walbaum) at Richmond Hill Fish Hatchery in Georgia. Ga. Game Fish Comm., Sport Fish. Div. Contrib. Serv. No. 2, 33 p.

McCleave, J.D., S.M. Fried, and A.K. Tout. 1977. Daily movements of shortnose sturgeon, Acipenser brevirostrum, in a Maine estuary. Copeia 1977(1):149-157.

McCoy, E.G. 1976. Assessment of North Carolina's river herring fishery. N.C. Dept. Nat. Econ. Res., Div. Mar. Fish., Mimeo Rep., [illegible]

McIlwain, T.D. 1967. Distribution of striped bass, Roccus saxatilis (Walbaum), in Mississippi waters. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 21:254-257.

McIlwain, T.D. 1974. Experimental stocking of striped bass. Compl. Rep., Proj. AFCS-4, 1970-73. Gulf Coast Res. Lab., Ocean Springs, MS, 6

McIlwain, T.D. 1979. Rearing and stocking striped bass - Mississippi Gulf coast. Annu. Prog. Rep. AFCS-6-2. 1 Oct. 1977 to 30 Sept. 1978. Gulf Coast Res. Lab., Ocean Springs, MS, 99 p.

McIlwain, T.D. 1980a. Striped bass in coastal waters, South Atlantic and Gulf. In Clepper, H. (ed.), Marine Recreational Fisheries. Vol. 5. Proc. of the Fifth Annu. Mar. Rec. Fish. Symp., Boston, MA, 27-28 March 1980, pp. 37-43.

McIlwain, T.D. 1980b. Rearing and stocking striped bass - Mississippi Gulf coast. Compl. Rep. Proj. AFCS-6. 1 Sept. 1976-30 Sept. 1979. Gulf Coast Res. Lab., Ocean Springs, MS, 86 p.

McKenzie, J.A. 1973. Comparative electrophoresis of tissues from blueback herring *Alosa aestivalis* (Mitchell) and gaspereau *Alosa pseudoharengus* (Wilson). Comp. Biochem. Physiol. 44(1B):65-68.

McLane, W.M. 1955. Fishes of the St. John's River System. Ph.D. Thesis, Univ. Fla., Tallahassee, 361 p.

McLane, W.M. 1958. Completion report for Dingell-Johnson Striped Bass Project F-4-R. Florida Game Freshwater Comm., Mimeo Rep., 16 p.

Meehan, W.E. 1910. Experiments in sturgeon culture. Trans. Am. Fish. Soc. 39:85-91.

Meldrim, J.W. and J.J. Gift. 1971. Temperature preference, avoidance and shock experiments with estuarine fishes. Ichthyol. Assoc. Bull. 7, 75 p.

Meldrim, J.W., J.J. Gift, and B.R. Petrosky. 1974. The effect of temperature and chemical pollutants on the behavior of several estuarine organisms. Ichthyol. Assoc. Bull. 11, 129 p.

Merriman, D. 1941. Studies on the striped bass (*Roccus saxatilis*) of the Altantic coast. U.S. Fish Wildl. Serv., Fish. Bull. 50:1-77.

Meth, F.F. 1973. Sport and commercial fisheries of the Saint John estuary. Saint John R. Basin Board Rep. 7b:1-70.

Michaels, R. 1980. Shad position statement - the current status of Georgia's shad fishery. Ga. Dept. Nat. Res., Game Fish Div., Mimeo Rep., 12 p.

Middaugh, D.P., J.A. Couch, and A.M. Crane. 1977. Responses to early life history stages of the striped bass, *Morone saxatilis*, to chlorination. Chesapeake Sci. 18:141-153.

Miller, P.E. 1977. Experimental study and modeling of striped bass egg and larval mortality. Ph.D. Thesis, The John Hopkins Univ., Baltimore, 99 p.

Miller, R.R. 1972. Threatened freshwater fishes of the United States. Trans. Am. Fish. Soc. 101:239-252.

Mills, J.G., Jr. 1972. Biology of the Alabama shad in northwest Florida. Florida Dept. Nat. Res., Div. Mar. Res., Mar. Res. Lab. Tech. Ser. No. 68, 23 p.

Morgan, R.P., II, and R.D. Prince. 1976. Chlorine toxicity to estuarine fish eggs and larvae. Chesapeake Biol. Lab. Univ. Md. Cent. Environ. Estuarine Stud. UMCEES Ref. 76-116 CBL, 122 p.

Morgan, R.P., II, and R.D. Prince 1977. Chlorine toxicity to eggs and larvae of five Chesapeake Bay fishes. Trans. Am. Fish. Soc. 106:380-385.

Morgan, R.P., II, V.J. Rasin, Jr., and R.L. Copp. 1981. Temperature and salinity effects on development of striped bass eggs and larvae. Trans. Am. Fish. Soc. 110:95-99.

Morgan, R.P., J.V. Rasin, and L.A. Noe. 1973. Effects of suspended sediments on the development of eggs and larvae of striped bass and white perch. Final Report. Army Corps of Engineers Contract No. DACW61-71-C-0062.

Morrow, J.E. 1974. Economic impacts of striped bass stocking in four countries located in northwest Florida. Part I. Base Data Study. Prepared for Div. Fishery Serv., S.E. Region, Bur. Sport. Fish. Wildl., U.S. Dept. Interior by Environmental Research Group, Georgia State Univ., 90 p.

Moss, D.D. 1946. Preliminary studies of the shad (Alosa sapidissima) catch in the lower Connecticut River 1944. Trans. N. Am. Wildl. Conf. 11:230-239.

Moss, S.A. 1970. The response of young American shad to rapid temperature changes. Trans. Am. Fish. Soc. 99:381-384.

Moss, S.A., W.C. Leggett, and W.A. Boyd. 1976. Recurrent mass mortalities of the blueback herring, Alosa aestivalis, in the lower Connecticut River. In Merriman, D. and L.M. Thorpe (eds.), The Connecticut River Ecological Study, the impact of a nuclear power plant. Am. Fish. Soc. Monogr. No. 1, pp. 227-234.

Murawski, S.A. and A.L. Pacheco. 1977. Biological and fisheries data on Atlantic sturgeon, Acipenser oxyrhynchus (Mitchell). U.S. Dept. Commer., Natl. Mar. Fish. Serv. Sandy Hook Lab. Tech. Ser. Rep. No. 10.

Natochin, Yu.V., V.I. Luk'yanenko, Ye.A. Lavrova, and G.F.Metallov. 1975. Cation content of the blood serum during the marine and river periods in the life sturgeons. J. Ichthyol. 15(5):799-804.

Neal, W.E. 1964. Striped bass study. Va. Dingell-Johnson Proj., Job Compl. Rep., Fed. Aid Proj. F-5-R-9, Warmwater Fish. Manage. Invest. Job 6 Coop. and Inland Fish., 14 p. Mimeo.

Neves, R.J. and L. Depres. 1979. The oceanic migration of American shad, Alosa sapidissima, along the Atlantic coast. NOAA Fish. Bull. 77(1):199-212.

Nichols, P.R. 1960. Homing tendency of American shad, Alosa sapidissima, in the York River, Virginia. Chesapeake Sci. 1:200-201.

Nichols, P.R. 1966a. The striped bass. U.S. Fish Wildl. Serv., Fish. Leafl. 592, 6 p. Mimeo.

Nichols, P.R. 1966b. Comparative study of juvenile American shad populations by fin ray and scute counts. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. 525, 10 p.

Nichols, P.R. and D.E. Louder 1970. Upstream passage of anadromous fish through navigation locks and use of the stream for spawning and nursery habitat, Cape Fear River, North Carolina, 1962-1966. U.S. Fish Wildl. Serv., Circ. 352, 12 p.

Nichols, P.R. and W.H. Massman. 1962. Abundance, age and fecundity of shad, York River, Va., 1953-59. U.S. Fish Wildl. Serv. Fish. Bull. 63:179-187.

Nicholson, W.R. 1964. Growth compensation in four year classes of striped bass, Roccus saxatilis, from Albemarle Sound, North Carolina. Chesapeake Sci. 5:145-149.

Norden, C.R. 1967. Development and identification of the larval alewife, Alosa pseudoharengus (Wilson), in Lake Michigan. Proc. Conf. Great Lakes Res. 10:70-78.

O'Rear, C.W., Jr. 1973. The toxicity of zinc and copper to striped bass eggs and fry with methods for providing confidence limits. Proc. 26th Annu. Conf. Southeast. Assoc. Game Fish Comm. 1972: 484-489.

Otto, R.G., M.A. Kitchel, and J.O. Rice. 1976. Lethal and preferred temperatures of the alewife (Alosa pseudoharengus) in Lake Michigan. Trans. Am. Fish. Soc. 105:96-106.

Otwell, W.S. and J.V. Merriner. 1975. Survival and growth of juvenile striped bass, Morone saxatilis, in a factorial experiment with temperature, salinity and age. Trans. Am. Fish. Soc. 104:560-566.

Pacheco, A.L. (ed.). 1968. Alewife, blueback herring, and American shad. Proceedings of a workshop on egg, larval, and juvenile stages of fish in Atlantic coast estuaries. NMFS Tech. Publ. No. 1.

Painter, R.E. and L.H. Wixom. 1967. Striped bass fishery and swimming endurance tests, p. 31-47. In Delta fish and wildlife protection study. Resource Agency of the State of California.

Parks, N.B. 1978. The Pacific Northwest commercial fishery for American shad. Mar. Fish. Rev. 40(2):29-31.

Pate, P.P., Jr. 1972. Life history aspects of the hickory shad, Alosa mediocris (Mitchell), in the Neuse River, North Carolina. M.S. Thesis, N.C. State Univ., Raleigh, N.C., 66 p.

Pate, P.P., Jr. 1974. Age and size composition of commercial catches of blueback herring and alewife in Albemarle Sound, N.C. and its tributaries. Proc. 27th Annu. Conf. Southeast Assoc. Game Fish Comm. 1973:560-569.

Pate, P.P., Jr. 1975. Anadromous fisheries research program - Tar River, Pamlico River, and N. Pamlico Sound, Annu. Rep. for Proj. AFCS-10. N.C. Dept. Nat. Res. Comm. Develop., Div. Mar. Fish., 69 p.

Pearson, J.C. 1938. The life history of the striped bass, or rockfish, Roccus saxatilis (Walbaum). U.S. Bur. Fish., Fish. Bull. 49:825-851.

Perkins, R.J. and M.D. Dahlberg. 1971. Fat cycles and condition factors of Altamaha River shads. Ecology 52(2):359-362.

Phillips, H.A. 1967. Striped bass propagation - fingerling rearing, Annu. Prog. Rep. F-16-R. N.C. Wildl. Res. Comm., Div. Inland Fish, 18 p. Mimeo.

Polgar, T.T., J.A. Mihursky, R.E. Ulanowicz, R.P. Morgan II, and J.S. Wilson. 1976. An analysis of 1974 striped bass spawning success in the Potomac estuary, pp. 151-165. In M. Wiley (ed.), Estuarine Processes. Vol. I. Uses, stresses and adaptation to the estuary. Acad. Press, N.Y.

Powell, M.R. Undated. Two years of brackish water pond culture of striped bass (Morone saxatilis) in South Alabama. Ala. Mar. Res. Div., Dept. Cons. and Nat. Res., 6 p. Mimeo.

Powell, M.R. 1976. Striped bass, Morone saxatilis, production and stocking experiments in Alabama coastal waters, Compl. Rep. on Proj. AFCS-6. Ala. Dept. Cons. Nat. Res., Mar. Res. Div., Mimeo.

Raney, E.C. 1952. The life history of the striped bass, Roccus saxatilis (Walbaum). Bull. Bingham Oceano. Collec. 14:5-97.

Raney, E.C. 1958. The striped bass. U.S. Fish Wildl. Serv., Fish. Leafl. 451, 6 p.

Raney, E.C. and W.S. Woolcott. 1955. Races of the striped bass, Roccus saxatilis (Walbaum), in Southeastern United States. J. Wildl. Mgt. 19:444-450.

Rathjen, W.F. and L.C. Miller. 1957. Aspects of the early life history of the striped bass (Roccus saxatilis) in the Hudson River. N.Y. Fish Game J. 4:43-60.

Redpath, G.S. 1972. Temperature and its effect on the growth and production of juvenile striped bass, Morone saxatilis. M.S. Thesis, Univ. California, Davis, 37 p.

Rehwoldt, R., G. Bida, and B. Nerrie. 1971. Acute toxicity of copper, nickel and zinc ions to some Hudson River fish species. Bull. Environ. Contam. Toxicol. 6:445-448.

Richardson, L.B., D.T. Burton, S.L. Margrey, and A. Rosenkranz. 1978. Egg and prolarval development of striped bass, Morone saxatilis (Walbaum), exposed to ozone produced oxidants in fresh and estuarine water. Assoc. Southeast. Biol. Bull. 25(2):40.

Ritchie, W.A. 1969. The archaeology of Martha's Vineyard. The National History Press, Garden City, N.Y., 253 p.

Rivas, L.R. 1954. The origin, relationships, and geographical distribution of the marine fishes of the Gulf of Mexico, pp. 503-505. In P.S. Galtsoff (ed.), Gulf of Mexico, its origins, waters, and marine life. U.S. Fish Wildl. Serv., Fish. Bull. 55(89):604 p.

Roedel, P.M., (ed.). 1974. Optimum sustainable yield as a concept in fisheries management. Proc. Symp. 104th Annu. meeting of Am. Fish Soc., Washington, D.C., 90 p.

Roelofs, E.W. 1951. The edible finfishes of North Carolina. In H.F. Taylor (ed.), Survey of marine fisheries of North Carolina. Univ. of North Carolina Press, Chapel Hill.

Rogers, B.A. and D.T. Westin. 1981. Laboratory studies on effects of temperature and delayed initial feeding on development of striped bass larvae. Trans. Am. Fish. Soc. 110:100-110.

Rogers, B.A., D.T. Westin, and S.B. Saila. 1977. Life stage duration studies on Hudson River striped bass. Univ. R.I., Applied Mar. Res. Group., NOAA Sea Grant., Mar. Tech. Rep. 31, 111 p.

Rothschild, B.J. 1966. Observations on the alewife (Alosa pseudoharengus) in Cayuga Lake. N.Y. Fish Game J. 13(2): 188-195.

Royce, W.F. 1943. The reproduction and studies of the life history of the lake trout, Cristovomer namaycush (Walbaum). Thesis, Cornell Univ. Abstracts of theses, 1943:297-300.

Ryder, J.A. 1887. On the development of osseus fishes, including marine and freshwater forms. U.S. Comm. Fish. Rep. (1885) 13: 489-604.

Ryder, J.A. 1890. The sturgeon and sturgeon industries of the eastern coast of the United States, with an account of experiments bearing upon sturgeon culture. U.S. Fish. Comm. Bull. (1888)8:321-328.

Saila, S.B., T.T. Polgar, D.J. Sheehy, and J.M. Flowers. 1972. Correlations between alewife activity and environmental variables at a fishway. Trans. Am. Fish. Soc. 101:583-594.

Scherer, M.D. 1975. Analysis of factors affecting passage of American shad (Alosa sapidissima Wilson) at Holyoke Dam, Massachusetts and assessment of juvenile growth and distribution above the dam. Ph.D. Dissertation, Univ. Mass., 262 p.

Schoumacher, R. 1969. Transportation of adult striped bass. Progr. Fish-Cult. 31:230.

Schubel, J.R. 1974. Effects of exposure to time-excess temperature histories typically experienced at power plants on the hatching success of fish eggs. Estuarine Coastal Mar. Sci. 2:105-116.

Schubel, J.R. and A.H. Auld. 1973. Hatching success of blueback herring and striped bass eggs with various time vs temperature histories. In J.W. Gibbons and R.R. Sharitz (eds.), Thermal Ecology, AFC Symp. Ser. (Conf. 730505), 1973.

Schwartz, F.J. and G.W. Link, Jr. 1976. Status of Atlantic, Acipenser oxyrhynchus, and shortnose, A. brevirostrum, sturgeons in North Carolina (Pisces, Acipenseridae). Assoc. Southeast. Biol. Bull. 23(2):94.

Scofield, E.C. 1928. Striped bass studies. Calif. Fish Game 14:29-37.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Board Can., Bull. 184, 966 p.

Scruggs, G.D., Jr. 1957. Reproduction of resident striped bass in Santee-Cooper Reservoir, South Carolina. Trans. Am. Fish. Soc. 85:144-159.

Setzler, E.M., W.R. Boynton, K.V. Wood, H.H. Zion, L. Lubbers, N.K. Mountford, P. Frere, L. Tucker, and J.A. Mihurskey. 1980. Synopsis of biological data on striped bass, Morone saxatilis (Walbaum). NOAA Tech. Rep. NMFS Circ. 433, 69 p.

Shannon, E.H. 1967. Preliminary observations of the effect of pH on egg hatch and fry survival of striped bass. Final Report, Job VII-B striped bass propagation - fingerling rearing. N.C. Wildl. Res. Comm., Div. Inland Fisheries, 2 p. Mimeo.

Shannon, E.H. 1970. Effect of temperature changes upon developing striped bass eggs and fry. Proc. 23rd Annu. Conf. Southeast. Assoc. Game Fish Comm. 1969:265-274.

Shannon, E.H. and W.B. Smith. 1968. Preliminary observations on the effect of temperature on striped bass eggs and sac fry. Proc. 21st Annu. Conf. Southeast Assoc. Game Fish Comm. 1967:257-260.

Shearer, L.W., D.E. Ritchie, Jr., and C.M. Frisbie. 1962. Sport fishing survey in 1960 of the lower Patuxent estuary and the 1958 year-class of striped bass. Chesapeake Sci. 3:1-17.

Shell, E.W. and J.R. Kelley, Jr. 1967. Project Proposal AFC-1-1 (27 January 1967). Research on striped bass, Roccus saxatilis, in Alabama rivers. Ala. Dept. Cons. Mimeo.

Shell, E.W. and J.R. Kelly, Jr. 1968. Research on striped bass, Roccus saxatilis, in Alabama rivers. Proj. No. AFC-1-1, 1 April 1967 to 31 March 1968. Ala. Dept. Cons. Mimeo.

Sherk, J.A., J.M. O'Connor, and D.A. Neumann. 1975. Effects of suspended and deposited sediments on estuarine environments, pp. 541-558. In L.E. Cronin (ed.), Estuarine Research. Vol. II. Geology and Engineering, Acad. Press, N.Y.

Sholar, T.M. 1975. Anadromous fisheries survey of the New and White Oak River Systems. N.C. Div. Mar. Fish., Compl. Rep. Oct. 73-June 75, Proj. AFC-9, 54 p.

Sholar, T.M. 1977a. Status of American shad in North Carolina, pp. 17-32. In Proceedings of a Workshop on American shad, 14-16 Dec. 1976, Amherst, MA.

Sholar, T.M. 1977b. Anadromous fisheries research program, Cape Fear River System, Phase I. Prog. Rep. for Proj. AFCS-12. N.C. Dept. Nat. Res. Comm. Develop., Div. Mar. Fish., 63 p.

Silvey, W.D. and G. Irwin. 1969. Relation of water quality to striped bass mortalities in the Carquinez Straight in California. Open-file report, U.S. Dept. Interior., Geol. Surv., Water Res. Div., 12 p.

Sindermann, C.J. and D.F. Mairs. 1961. Blood properties of prespawning and postspawning anadromous alewives, Alosa pseudoharengus. U.S. Fish Wildl. Serv., Fish. Bull. 61, 7 p.

Skinner, J.E. 1974. A functional evaluation of a large louver screen installation and fish facilities research on California water diversion projects, pp. 225-250. In L.D. Jensen (ed.), Second workshop on entrainment and intake screening. Elec. Power Res. Inst., Palo Alto, Calif. EPRI Publ. No. 74-049-00-5.

Smith, B.A. 1971. The fishes of four low salinity tidal tributaries of the Delaware River Estuary. M.S. Thesis, Cornell Univ., 304 p.

Smith, H.M. 1899. Notes on the extent and condition of alewife fisheries of the United States in 1896. In Commissionsers Report 1898. U.S. Commission Fish. and Fisheries, Part 4:33-43.

Smith, H.M. 1907. The fishes of North Carolina. N.C. Geol. Econ. Surv. 2, 453 p.

Smith, H.M. 1917. Report of the United States Commission of fisheries for fiscal year ended June 30, 1915. Bur. Fish. Document No. 827:70.

Smith, L.D. 1968. Notes on the distribution, relative abundance and growth of juvenile anadromous fish in the Altamaha River system, Georgia, with specific reference to striped bass, Roccus saxatilis (Walbaum). Ga. Game Fish Comm., Sport Fish. Div., Brunswick, Ga., Contrib. Ser. No. 1, 22 p.

Smith, L.D. 1970. Life history studies of striped bass. Final Report, AFS-2. Ga. Dept. Nat. Res. Sport Fish. Div., 134 p.

Smith, L.D. 1973. Life history studies of striped bass. Ga. Dept. Nat. Res., Game and Fish Div., Fish. Section, Sport Fish. Div., 143 p.

Smith, M.A. 1975. Northwest Florida striped bass investigation, Choctawhatchee Bay study, final report. U.S. Fish and Wildlife Service, Panama City, Fla., 93 p.

Smith, T.I.J. 1979. Life history, ecology, culture and management of the Altantic sturgeon, Acipenser oxyrhynchus oxyrhynchus Mitchell, in South Carolina. Prog. Rep. on Proj. AFS-9-2, 1 Oct. 1978-30 Sept. 1979, 11 p. Mimeo.

Smith, T.I.J., E.K. Dingley, and D.E. Marchette. 1980. Induced spawning and culture of Atlantic sturgeon, Acipenser oxyrhynchus (Mitchell). Progr. Fish-Cult. 42(3):147-151.

Spitsbergen, D.L. and M. Wolff. 1974. Survey of nursery areas in western Pamlico Sound, North Carolina, Compl. Rep. Proj. No. 2-175-R. N.C. Dept. Nat. Econ. Res., Div. Comm. Sport Fish., 80 p.

Stanley, J.G. 1969. Seasonal changes in the electrolyte metabolism in the alewife, Alosa pseudoharengus, in Lake Michigan. Proc. Conf. Great Lakes Res. 12:91-97.

Sterling, J.S. and W.F. Godwin. 1970. A final report for North Carolina anadromous fish project AFC-5-1 covering the period February 1, 1968 to March 31, 1969. N.C. Dept. Conserv. and Develop., Div. Comm. Sport Fish., Raleigh, Mimeo.

Stevens, D.E. 1977. Striped bass (Morone saxatilis) year class strength in relation to river flows in the Sacremento - San Joaquin Estuary, California. Trans. Am. Fish. Soc. 106:34-42.

Stevens, R.E. 1958. The striped bass of the Santee-Cooper Reservoir. Proc. 11th Annu. Conf. Southeast. Assoc. Game Fish Comm. 1957:253-264.

Stevenson, C.H. 1899. The shad fisheries of the Atlantic coast of the United States. U.S. Comm. Fish Rep. (1898)24:101-269.

St. Pierre, R. 1977. Preface to Proceedings of a workshop on American shad, 14-16 Dec. 1976, Amherst, MA.

Street, M.W. 1970. Some aspects of the life histories of hickory shad, Alosa mediocris (Mitchell), and blueback herring, Alosa aestivalis (Mitchell), in the Altamaha River, Georgia. M.S. Thesis, Univ. Ga., Athens, 89 p.

Street, M.W. 1975. The status of striped bass in Albemarle Sound, North Carolina. N.C. Div. Mar. Fish., Mimeo Rep., 19 p.

Street, M.W. 1980. Trends in North Carolina's commercial fisheries, 1965-1979. N.C. Dept. Nat. Res. and Comm. Develop., Div. Mar. Fish., Mimeo.

Street, M.W. and J.G. Adams. 1969. Aging of hickory shad and blueback herring in Georgia by the scale method. Ga. Game Fish. Comm., Mar. Fish Div., Contrib. Ser. No. 18, 13 p.

Street, M.W., P.P. Pate, B.F. Holland, Jr., and A.B. Powell. 1975. Anadromous fisheries research program, northern coastal region. Compl. Rep., Proj. AFCS-8, N.C. Div. Mar. Fish., 173+62+Append.

Swingle, W. 1968. Ala. Dept. Conserv., Seafoods Div, Ala. Mar. Resource Lab., Mar. Fish. Res. Mgt. Act. annual report. 1 Oct. 67-30 Sept. 68, pp. 15-23.

Swingle, W. 1971. Striped bass, Morone saxatilis, production to establish commercial stocks in Alabama estuaries. Proposal for Ala. Proj. AFC-3, Mimeo.

Sykes, J.E. 1956. Shad fishery of the Ogeechee River, Georgia in 1954. U.S. Fish Wildl. Serv. Spec. Sci. Rep. 191:1-11.

Sykes, J.E. and B.A. Lehman. 1957. Past and present Delaware River shad fishery and considerations for its future. U.S. Fish Wildl. Serv., Res. Rep. 46, 25 p.

Sytina, L.A. 1975. Divergence of features in the course of early ontogenetic development of the larvae of closely related species of sturgeons. J. Ichthyol. 15(4):594-606.

Tagatz, M.E. 1961. Tolerance of striped bass and American shad to changes of temperature and salinity. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 388, 8 p.

Talbot, G.B. 1954. Shad in the Hudson. New York State Cons. 8(5):17-19.

Talbot, G.E. 1954. Factors associated with fluctuations in abundance of Hudson River shad. U.S. Fish Wildl. Serv. Fish. Bull. 56:373-413.

Tatum, B.L., J.D. Bayless, E.G. McCoy, and W.B. Smith. 1965. Preliminary experiments in the artificial propagation of striped bass, Roccus saxatilis. N.C. Wildl. Res. Comm., Div. Inland Fisheries, 14 p.

Tatum, B.L., J.D. Bayless, E.G. McCoy, and W.B. Smith. 1966. Preliminary experiments in an artificial propagation of striped bass, Roccus saxatilis. Proc. 19th Annu. Conf. Southeast. Assoc. Game Fish Comm. 1965:374-389.

Taubert, B.D. 1980. Reproduction of shortnose sturgeon (Acipenser brevirostrum) in Holyoke Pool, Connecticut River, Massachusetts. Copeia. 1980(1):114-117.

Taubert, B.D. and M.J. Dadswell. 1980. Description of some larval shortnose sturgeon (Acipenser brevirostrum) from the Holyoke Pool, Connecticut River, Massachusetts, USA, and the Saint John River, New Brunswick, Canada. Can. J. Zool. 58(6):1125-1128.

Tiller, R.E. 1943. Indications of compensatory growth in the striped bass, Roccus saxatilis Walbaum, as revealed by a study of the scales. Chesapeake Biol. Lab. Publ. 57, 16 p.

Trent, W.L. 1962. Growth and abundance of young-of-the-year striped bass, Roccus saxatilis (Walbaum), in Albemarle Sound, North Carolina. M.S. Thesis, N.C. State Univ., Raleigh, 66 p.

Trent, L. and W.W. Hassler, 1966. Feeding behavior of adult striped bass, Roccus saxatilis, in relation to stages of sexual maturity. Chesapeake Sci. 7:189-192.

Trent, L. and W.W. Hassler. 1968. Gill net selection, migration, size and age composition, sex ratio, harvest efficiency and management of striped bass in the Roanoke River, North Carolina. Chesapeake Sci. 9:217-232.

Tyus, H.M. 1971. Population size, harvest and movements of alewives, Alosa pseudoharengus (Wilson), during spawning migrations to Lake Mattamuskeet, North Carolina. Ph.D. Dissertation, N.C. State Univ., Raleigh, 77 p.

Tyus, H.M. 1972. Notes on the life history of the alewife, Alosa pseudoharengus, in North Carolina. J. Elisha Mitchell Sci. Soc. 88(4):240-243.

Ulanowicz, R.E. 1975. The mechanical effects of water flow on fish eggs and larvae, pp. 77-87. In S.B. Saila (ed.), Fisheries and energy production: a symposium. Lexington Books, Lexington, MA.

Ulrich, G., N. Chipley, J.W. McCord, and D. Cupka. 1979. Development of fishery management plans for selected anadromous fishes in South Carolina/Georgia. Special Scientific Rep. No. 14, Mar. Res. Center, S.C. Wildl. Mar. Res. Dept., 135 p.

Vladykov, V.D. and J.R. Greeley. 1963. Order Acipenseridae, pp. 24-60. In Fishies of the Western North Atlantic. Sears Found. Mar. Res., Mem. 1 (Part 3).

Wade, W.C. 1971. Commercial anadromous fishery, Edisto River, South Carolina. S.C. Wildl. Mar. Res. Dept., Annu. Prog. Rep. 1 June 1970-31 May 1971, 49 p.

Walburg, C.H. 1954. Experimental transportation of live shad past Susquehanna River dams. U.S. Fish Wildl. Serv. Spec. Sci. Rep. - Fish. No. 114, 13 p.

Walburg, C.H. 1956. Commercial and sport shad fisheries of the Edisto River, South Carolina. U.S. Fish Wildl. Serv. Spec. Sci. Rep. - Fish. No. 187, 9 p.

Walburg, C.H. 1957. Neuse River shad investigations, 1953. U.S. Fish Wildl. Serv., Spec. Sci. Rep. - Fish. 206, 13 p.

Walburg, C.H. 1960a. Abundance of St. Johns River shad. Trans. 25th North Am. Wildl. Nat. Res. Conf., pp. 327-333.

Walburg, C.H. 1960b. Abundance and life history of the shad, St. Johns River, Florida. U.S. Fish Wildl. Serv. Fish. Bull. 60:487-501.

Walburg, C.H. and P.R. Nichols. 1967. Biology and management of the American shad and the status of fisheries, Atlantic coast of the United States, 1960. U.S. Fish Wildl. Serv., Spec. Sci. Rep. - Fish. 550, 100 p.

Walburg, C.H. and J.E. Sykes. 1957. Shad fishery of Chesapeake Bay with special emphasis on the fishery of Virginia. U.S. Fish Wildl. Serv. Res. Rep. 48, 26 p.

Ware, F.J. 1971. Some early life history of Florida's inland striped bass, Morone saxatilis. Proc. 24th Annu. Conf. Southeast. Assoc. Game Fish Comm. 1970:439-447.

Warner, R.W. and S.C. Katkansky, 1970. An inflammatory lesion in an American shad, Alosa sapidissima. J. Fish Res. Board Can. 27(1):191-193.

Weaver, C.R. 1965. Observations on the swimming ability of adult American shad (Alosa sapidissima). Trans. Am. Fish. Soc. 94:382-385.

Whaley, G., C. Parker, B. Salem, J. Wilkerson, and A. Roach. 1970. An interim report on the striped bass (rockfish) in Georgia to the 1970 House of Representatives. The Rockfish Study Committee of the Game and Fish Committee of the House of Representatives, 12 p.

Whaley, G., H. Rainey, C. Parker, G.D. Adams, and H. Leggett. 1969. A report to the Legislature on the striped bass (rockfish) in Georgia; its status, potential and current research and management efforts by the State Game and Fish Commission. The Striped Bass Subcommittee of the House of Representatives, 9 p.

White, M.G., III, and T.A. Curtis. 1969. Anadromous fish survey of the Black River and Pee Dee River watersheds, Proj. AFS-2-4 S.C. Wildl. Mar. Res. Dept. Job. Prog. Rep., 1 July 1968-30 June 1969, 73 p.

White, R.L. and J.T. Lane. 1967. Evaluation of the shad fishery in Delaware Bay. N.J. Dept. of Cons. and Econ. Dev., Div. Fish Game, Mimeo.

White, R.L., J.T. Lane, and P.E. Hamer. 1969. Population and migration study of major anadromous fish. N.J. Dept. Cons. and Econ. Dev., Div. Fish. Game, Misc. Rep. No. 3M.

Whitworth, W.R. 1969. Effects of simultaneous variation of temperature and dissolved oxygen on the resistance of fishes to controlled pollutants. Res. Proj. Tech. Compl. Rep., 2 p. Selected Water Resources Abstracts 3(7), 1970, p. 35.

Wigfall, M. and J.M. Barkaloo. 1975. A preliminary report on the abundance and biology of stocked striped bass in the Choctawhatchie River System, Florida. Proc. 29th Annu. Conf. Southeast. Assoc. Game Fish Comm. 1975:152-155.

Williams, R.O. and G.E. Bruger. 1972. Investigations on American shad in the St. Johns River. Fla. Dept. Nat. Res., Tech. Ser. 66, 49 p.

Williams, R. and W. Gray. 1975. Stream survey section of anadromous fish project, 13 p. In Williams et al. (1975), Study of anadromous fishes of Florida. Manuscript Completion Report NMFS Grant-in-aid Program, AFCS-5. Florida Dept. Nat. Res., Mar. Res. Lab., Mimeo.

Williams, R., W. Gray, and J. Huff. 1975. Study of anadromous fishes of Florida. Manuscript Completion Report NMFS Grant-in-aid Program, AFCS-5. Florida Dept. Nat. Res., Mar. Res. Lab., 160 p.

Winters, G.H., J.A. Moores, and R. Chaulk. 1973. Northern range extension and probable spawning of gaspereau (*Alosa pseudoharengus*) in the Newfoundland area. J. Fish. Res. Board Can. 30:860-861.

Wooley, C.M., E.J. Crateau, and P.A. Moon. 1981a. Observations of Gulf of Mexico sturgeon (*Acipenser oxyrhynchus desotoi*) in the Apalachicola River, Florida. Unpub. manuscript, U.S. Fish Wildl. Serv., Office of Fishery Assistance, Panama City, Fla., 11 p.

Wooley, C.M., P.A. Moon, and E.J. Crateau. 1981b. A larval Gulf of Mexico sturgeon (*Acipenser oxyrhynchus desotoi*) from the Apalachicola River, Florida. Unpubl. manuscript, U.S. Fish Wildl. Serv., Office of Fishery Assistance, Panama City, Fla., 3 p.

APPENDIX A

ANADROMOUS SPECIES QUESTIONNAIRE FOR COMPLETING
A SOUTHEASTERN ANADROMOUS SPECIES MANAGEMENT PLAN

STATE	
DEPARTMENT COMPLETING QUESTIONNAIRE	
NAME	
TITLE	
ADDRESS	
TELEPHONE	

DECLINING ANADROMOUS FISH STOCKS

I. Using the numbers from the key, please indicate the relative importance of the categories as they pertain to declining anadromous fish stocks in your state.

	SPECIES	Atlantic sturgeon	Shortnose sturgeon	Striped bass (Atl. race)	Striped bass (Gulf race)	Striped/white bass hybrid	American shad	Hickory shad	Alabama shad	Alewife	Blueback herring	Skipjack herring	Other (specify):
HABITAT MANAGEMENT	Other:												
	Poor water quality												
	Spawning areas too accessible to fishermen												
	Poor food availability areas												
	Reduction in nursery areas												
	Reduction in spawning habitat												
	Reduced freshwater input to estuaries												
	Inadequate control of water release (dams)												
	Inadequate fishway facilities												
CHEMICAL DISTURBANCES	Other:												
	Sewerage outfalls												
	Low oxygen levels												
	Turbidity												
	Thermal effluents												
	Chemical pollution (e.g., heavy metals)												
	Acid rain												
PHYSICAL DISTURBANCES	Other:												
	Road construction												
	Location of industrial discharges												
	Industrial water intakes												
	Dams and impoundments												
	Bulkheading												
	Dredge and fill projects												
	Channelization												

KEY:
- 4 - Very important
- 3 - Important
- 2 - Does not contribute to declining fish stocks
- 1 - Inadequate information

DECLINING ANADROMOUS FISH STOCKS

II. Please write the names of river systems in your state in the appropriate spaces, and then indicate the relative importance of the categories as they pertain to DECLINING ANADROMOUS FISH STOCKS in your state.

HABITAT MANAGEMENT

- Other:
- Poor water quality
- Spawning areas too accessible to fishermen
- Poor food availability areas
- Reduction in spawning nursing habitat
- Reduced freshwater input to estuaries
- Inadequate control of water release (dams)
- Inadequate fishway facilities

CHEMICAL DISTURBANCES

- Other:
- Sewerage outfalls
- Low oxygen levels
- Turbidity
- Thermal effluents
- Chemical pollution (e.g., heavy metals)
- Acid rain

PHYSICAL DISTURBANCES

- Other:
- Road construction
- Location of industrial discharges
- Industrial water intakes
- Dams and impoundments
- Bulkheading
- Dredge and fill projects
- Channelization

LIST YOUR RIVER SYSTEMS

KEY:
4 - Very important
3 - Important
2 - Does not contribute to declining fish stocks
1 - Inadequate information

KEY: 4 - Very important
3 - Important
2 - Does not contribute to declining fish stocks
1 - Inadequate information

DECLINING ANADROMOUS FISH STOCKS (continued)

III. Please indicate the relative importance of the following categories as they pertain to DECLINING ANADROMOUS FISH STOCKS in your state.

A. FISHERIES MANAGEMENT

1. 4 3 2 1 Overfishing within state waters
2. 4 3 2 1 Competition by other species
3. 4 3 2 1 Overabundance of natural predators
4. 4 3 2 1 Decline in egg viability
5. 4 3 2 1 Exploitation of parental stocks by other states or countries (international waters)
6. 4 3 2 1 Other (specify):

B. REGULATORY ASPECTS

1. 4 3 2 1 Lack of coordinated effort between STATE AND FEDERAL agencies
2. 4 3 2 1 Lack of coordinated effort between agencies of BORDERING STATES
3. 4 3 2 1 Lack of coordinated effort among agencies WITHIN YOUR STATE
4. 4 3 2 1 Lack of funding to DEVELOP NEW management programs
5. 4 3 2 1 Lack of funding to MAINTAIN CURRENT management programs
6. 4 3 2 1 ___ Inadequate ___ Adequate ___ Too many INTERNATIONAL agreements for territorial fishing rights protecting the offshore spawning stock (check one)
7. 4 3 2 1 ___ Inadequate ___ Adequate ___ Too many FEDERAL laws, regulations and policies (check one)
8. 4 3 2 1 ___ Inadequate ___ Adequate ___ Too many STATE laws, regulations and policies (check one)
9. 4 3 2 1 ___ Inadequate ___ Adequate ___ Too many LOCAL LAWS, regulations and policies (check one)
10. 4 3 2 1 Other regulatory aspects (specify):

GOALS AND POLICIES

IV. Please use the IDENTIFYING NUMBERS from the following species list to answer questions concerning the goals and policies for fishery management in your state.

KEY: Use the identifying numbers 1-12.

1 - Atlantic sturgeon
2 - Shortnose sturgeon
3 - Striped bass (Atlantic race)
4 - Striped bass (Gulf race)
5 - Striped bass x white bass hybrid
6 - American shad
7 - Hickory shad
8 - Alabama shad
9 - Alewife
10 - Blueback herring
11 - Skipjack herring
12 - Other (specify):

MANAGEMENT PLAN is defined here as a document containing historical background, current information, a biological review, goal formulation, specified objectives, and detailed planning.

GOALS AND POLICIES (continued)

1. ______________________ From the list provided, please indicate which fish species have (or had) spawning runs in your state.

2. ______________________ List those species which are present in your state but are NOT PRESENTLY INCLUDED in a fishery management plan (e.g., state, federal, regional).

3. ______________________ List those species which are present in your state and which WILL PROBABLY BE INCLUDED in future management plans (e.g., state, federal, regional).

4. ______________________ List those species presently included on your STATE LIST of endangered or threatened species.

5. ______________________ List those species which provide an annual COMMERCIAL harvest.

6. ______________________ List those species presently managed for OPTIMUM YIELD.

7. ______________________ Do you restrict the COMMERCIAL fishing effort, during spawning season, for any of these species? YES NO If yes, list species.

8. ______________________ Do you prohibit COMMERCIAL fishing on or near spawning grounds during spawning season? YES NO If yes, list species.

9. ______________________ Do you prohibit COMMERCIAL fishing altogether for any species? YES NO If yes, list species.

10. ______________________ Do you regulate COMMERCIAL gear types and require that they be selective for a particular species? YES NO If yes, list species.

11. ______________________ Do you set minimum fish lengths for legal COMMERCIAL catch? YES NO If yes, list species.

KEY: Use the identifying numbers 1-12.

1 - Atlantic sturgeon	7 - Hickory shad
2 - Shortnose sturgeon	8 - Alabama shad
3 - Striped bass (Atlantic race)	9 - Alewife
4 - Striped bass (Gulf race)	10 - Blueback herring
5 - Striped bass x white bass hybrid	11 - Skipjack herring
6 - American shad	12 - Other (specify):

12. ______________________ Do you limit the number or weight taken by COMMERCIAL fisheries? YES NO If yes, list species.

13. ______________________ List those species which provide an annual SPORT harvest.

14. ______________________ List those species managed for SPORT use.

15. ______________________ Do you restrict SPORT fishing effort during spawning season? YES NO If yes, list species.

16. ______________________ Do you prohibit SPORT fishing on or near spawning grounds during spawning season? YES NO If yes, list species.

17. ______________________ Do you prohibit SPORT fishing altogether for any species? YES NO If yes, list species.

18. ______________________ Do you restrict SPORT fishing gear types? YES NO If yes, list species.

19. ______________________ Do you restrict or regulate SPORT fishing bait types? YES NO If yes, list species.

20. ______________________ Do you set minimum fish lengths for legal SPORT catch? YES NO If yes, list species.

21. ______________________ Do you set creel limits for any of these species? YES NO If yes, list species.

22. ______________________ Do you have NATIVE GROUPS (e.g., Indians) or RESIDENTS in your state to which a portion of the anadromous resource is allocated? YES NO If yes, list species.

MITIGATION

V. Continue using the IDENTIFYING NUMBERS from the species list to answer questions concerning mitigative efforts to restore anadromous fish stocks in your state.

1. ______________________ Do you have a formal plan for stocking anadromous fish in your state? YES NO If yes, list species.

KEY: Use the identifying numbers 1-12.

1 - Atlantic sturgeon	7 - Hickory shad
2 - Shortnose sturgeon	8 - Alabama shad
3 - Striped bass (Atlantic race)	9 - Alewife
4 - Striped bass (Gulf race)	10 - Blueback herring
5 - Striped bass x white bass hybrid	11 - Skipjack herring
6 - American shad	12 - Other (specify):

MITIGATION (continued)

2. ____________________ Are you REHABILITATING existing spawning runs to some level through stocking? YES NO If yes, list species.

3. ____________________ Are you RESTORING spawning runs which no longer exist through stocking? YES NO If yes, list species.

4. ____________________ Are you CREATING new spawning runs in river systems which appear conducive to anadromous fish? YES NO If yes, list species.

5. ____________________ Are you presently stocking to manage commercial and sport use of the anadromous fishery at an optimum yield level? YES NO If yes, list species.

6. ____________________ Have you established, or are you presently establishing, hatcheries to support your stocking efforts? YES NO If yes, list species.

7. ____________________ Do you support stocking efforts from state-issued commercial and/or sport STAMP REVENUES? YES NO If yes, list species.

8. ____________________ Do you support stocking from only STATE funds? YES NO Which species apply?

9. ____________________ Do you support stocking efforts from both STATE and FEDERAL funds? YES NO If yes, which species receive support?

10. ____________________ Have you constructed fishway facilities? YES NO For which species?

11. ____________________ Have you attempted to create new spawning sites? YES NO For which species?

12. ____________________ Have you attempted to increase fish access to present spawning sites by removal of barriers, fallen trees, channelization etc? YES NO For which species?

KEY: Use the identifying numbers 1-12.

1 - Atlantic sturgeon	7 - Hickory shad
2 - Shortnose sturgeon	8 - Alabama shad
3 - Striped bass (Atlantic race)	9 - Alewife
4 - Striped bass (Gulf race)	10 - Blueback herring
5 - Striped bass x white bass hybrid	11 - Skipjack herring
6 - American shad	12 - Other (specify):

13. ____________________ Have you attempted to improve or increase nursery areas? YES NO For which species?

14. ____________________ Do you presently manipulate predator and competitor populations to favor survival of anadromous populations? YES NO For which species?

15. ____________________ Do you presently control spawning grounds accessibility to sport and commercial fishermen? YES NO If yes, for which species?

16. ____________________ Do you presently regulate or control water release from impoundments during spawning season? YES NO For which species?

17. ____________________ Does your state presently have an anadromous species management plan? YES NO For which species?

18. ____________________ If no, are there plans to develop one in the near future? YES NO For which species?

SPAWNING RUN IDENTIFICATION

VI. The determination of the distribution, abundance and status of anadromous fish stocks is important in formulating future goals and objectives. Please answer the following questions as completely as possible.

1. Were any of the spawning runs in your state rehabilitated or introduced by STOCKING, LOCKING, construction of FISHWAY FACILITIES, or other methods? YES NO If yes, please indicate the success of the program:

SUCCESS:	1 - Highly successful	3 - No change
	2 - Somewhat successful	4 - Too early to judge

SPECIES	RIVER SYSTEM	YEARS	SUCCESS
____________	____________________	________	1 2 3 4
____________	____________________	________	1 2 3 4
____________	____________________	________	1 2 3 4

SPAWNING RUN IDENTIFICATION

2. Please list the rivers in your state in the appropriate spaces, then indicate which species have (or had) spawning runs in your state and indicate the status of the run.

LIST THE RIVERS WITHIN, OR BORDERING, YOUR STATE

STATUS:
0 - Probably never present
1 - Increasing
2 - Stable
3 - Declining
4 - Threatened
5 - No longer present
6 - Not known

SPECIES	ATLANTIC STURGEON	SHORTNOSE STURGEON	STRIPED BASS (ATL. RACE)	STRIPED BASS (GULF RACE)	STRIPED/WHITE BASS HYBRID	AMERICAN SHAD	HICKORY SHAD	ALABAMA SHAD	ALEWIFE	BLUEBACK HERRING	SKIPJACK HERRING	OTHER (specify):

3. Please list the river systems in your state which are no longer suitable for anadromous fish species, and why.

VII. STOCKING

1. Do you now receive anadromous species of fish from the federal government produced at national fish hatcheries for stocking in waters that are not landlocked? YES NO If yes, complete the following:

	SPECIES	NUMBER RECEIVED EACH YEAR
Requirements now:		
Estimate of future needs:		
1982:		
1985:		

2. Do you depend on PRIVATE or OUT-OF-STATE sources of fish for stocking efforts? YES NO If yes, identify the species supplied and the source.

3. List the rivers in your state which have first priority for stocking efforts:

4. List the departments within your state which have the responsibility to manage populations of anadromous fish:

Is management a joint responsibility? YES NO

VIII. RESEARCH NEEDS

What important research do you feel is necessary to compliment the anadromous species program in your state?

Additional comments, criticicms and suggestions are welcome:

Table 4.1-1. Question I. Relative importance of CHANNELIZATION as a possible contributor to declining anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = response by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA	American shad (FC) Hickory shad (FC) Alewife (F) Blueback herring (F)	A Striped bass (C) Alewife (C) Blueback herring (C)	Atl. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S)	Alewife (S) Blueback herring (S) A Striped bass (F) Atl. sturgeon (C) Short. sturgeon (C)	
SOUTH CAROLINA				Atl. sturgeon (FS) Short. sturgeon (FS) A Striped bass (FS) American shad (FS) Hickory shad (FS) Blueback herring (FS)	
GEORGIA	Atl. sturgeon (S) Short. sturgeon (S) American shad (S) Hickory shad (S)	A Striped bass (S)		A Striped bass (F) Skipjack herring (FS) G Striped bass (FS) SB/WB cross (S) American shad (F) Hickory shad (F) Alabama shad (FS) Alewife (S) Blueback herring (FS) Short. sturgeon (FS) Atl. sturgeon (F)	SB/WB cross (F)
FLORIDA	A Striped bass (F) G Striped bass (F) American shad (F) Alabama shad (S) Gulf sturgeon (S)	Hickory shad (S) Blueback herring (S) American shad (S)	Atl. sturgeon (S)	Atl. sturgeon (F) Hickory shad (F) Alabama shad (F) Alewife (F) Blueback herring (F) Skipjack herring (F)	SB/WB cross (F)

APPENDIX B

Table 4.1-2. Question I, DREDGE AND FILL (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
FLORIDA	A Striped bass (F) G Striped bass (F) American shad (F)		Atl. sturgeon (S) Alabama shad (S) Gulf sturgeon (S)	Atl. sturgeon (F) Short. sturgeon (F) Hickory shad (FS) Alabama shad (F) Alewife (F) Blueback herring (FS) Skipjack herring (F) American shad (S)	SB/WB cross [illegible]
ALABAMA				Gulf sturgeon (FS) G Striped bass (FS) Alabama shad (FS) Skipjack herring (FS) Short. sturgeon (S)	SB/WB cross [illegible] A Striped ba[illegible]
MISSISSIPPI				A Striped bass G Striped bass	
LOUISIANA				Gulf sturgeon A Striped bass Alabama shad SB/WB cross	

Table 4.1-3. Question I. Relative importance of BULKHEADING as a possible contributor to declining anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = response by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA			A Striped bass (FS) Atl. sturgeon (S) American shad (S) Hickory shad (S) Alewife (S) Blueback herring (S)	American shad (FC) Hickory shad (FC) Alewife (FC) Blueback herring (FC) Atl. sturgeon (C) Short. sturgeon (C) A Striped bass (C)	
SOUTH CAROLINA			Atl. sturgeon (S) Short. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S) Blueback herring (S)		
GEORGIA				All anadromous species (FS)	SB/WB cross (F)
FLORIDA		A Striped bass (F) G Striped bass (F) American shad (F)	Atl. sturgeon (S) Alabama shad (S)	Atl. sturgeon (F) Short. sturgeon (F) Hickory shad (FS) Alabama shad (F) Alewife (F) Blueback herring (FS) Skipjack herring (F) American shad (S) Gulf sturgeon (S)	SB/WB cross (F)

Table 4.1-3. Question I, BULKHEADING (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
ALABAMA		Gulf sturgeon (F) G Striped bass (F) Alabama shad (F) Skipjack herring (F)		Gulf sturgeon (S) Short. sturgeon (S) G Striped bass (S) Alabama shad (S) Skipjack herring (S)	SB/WB cross (FS) A Striped bass (S)
MISSISSIPPI				A Striped bass G Striped bass	
LOUISIANA				Atl. sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-4. Question I. Relative importance of DAMS AND IMPOUNDMENTS as possible contributors to declining anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = response by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA	American shad (FC) Hickory shad (FC) Alewife (FC) Blueback herring (FC) Atl. sturgeon (C) Short. sturgeon (C) A Striped bass (C)	A Striped bass (F)	A Striped bass (S) Hickory shad (S) Alewife (S) Blueback herring (S) American shad (S) Atl. sturgeon (S)		
SOUTH CAROLINA	Blueback herring (S)	Atl. sturgeon (S) Short. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S)			
GEORGIA	Atl. sturgeon (S) Short. sturgeon (S) American shad (S) Hickory shad (S)	G Striped bass (F) Alabama shad (F)	A Striped bass (F) American shad (F) Hickory shad (F) Blueback herring (F)	Short. sturgeon (F) Atl. sturgeon (F) Skipjack herring (FS) Blueback herring (S) A Striped bass (S) G Striped bass (S) SB/WB cross (S) Alabama shad (S) Alewife (S)	SB/WB cross (F)
FLORIDA	Atl. sturgeon (S) A Striped bass (F) American shad (F) Gulf sturgeon (S) Alabama shad (S)		Hickory shad (S) Blueback herring (S) American shad (S)	Atl. sturgeon (F) Short. sturgeon (F) G Striped bass (F) Hickory shad (F) Alabama shad (F) Alewife (F) Blueback herring (F) Skipjack herring (F)	SB/WB cross (F)

Table 4.1-4. Question I, DAMS AND IMPOUNDMENTS (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
ALABAMA	Gulf sturgeon (FS) G Striped bass (FS) Alabama shad (FS) Short. sturgeon (S) Skipjack herring (S)			Skipjack herring (F)	SB/WB cross (FS) A Striped bass
MISSISSIPPI				A Striped bass G Striped bass	
LOUISIANA	Gulf sturgeon G Striped bass			A Striped bass Alabama shad SB/WB cross	
TEXAS	G Striped bass				

Table 4.1-5. Question I. Relative importance of <u>INDUSTRIAL WATER INTAKES</u> as possible contributors to declining anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = response by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA	A Striped bass (F) American shad (F) Hickory shad (F) Alewife (F) Blueback herring (F)	Atl. sturgeon (C) Short. sturgeon (C) A Striped bass (C) American shad (C) Hickory shad (C) Alewife (C) Blueback herring (C)		A Striped bass (S) American shad (S) Hickory shad (S) Alewife (S) Blueback herring (S) Atl. sturgeon (S)	
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA				All anadromous species (FS)	SB/WB cross (F)
FLORIDA		American shad (S) Hickory shad (S) Blueback herring (S)	A Striped bass (F) G Striped bass (F) Atl. sturgeon (S) Alabama shad (S) Gulf sturgeon (S)	Atl. sturgeon (F) Short. sturgoen (F) American shad (F) Hickory shad (F) Alabama shad (F) Blueback herring (F) Skipjack herring (F)	SB/WB cross (F)
ALABAMA			Atl. sturgeon (S) Short. sturgeon (S) Alabama shad (S) Skipjack herring (S) G Striped bass (S)	Gulf sturgeon (F) G Striped bass (F) Alabama shad (F) Skipjack herring (F)	SB/WB cross (FS) A Striped bass (S)
MISSISSIPPI				A Striped bass G Striped bass	
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass Alabama shad S[illegible]B c[illegible]	

Table 4.1-6. Relative importance of the LOCATION OF INDUSTRIAL DISCHARGES as a possible contributor to declining anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA	A Striped bass (FC) American shad (FC) Hickory shad (FC) Alewife (FC) Blueback herring (FC) Atl. sturgeon (C) Short. sturgeon (C)			A Striped bass (S) American shad (S) Hickory shad (S) Alewife (S) Blueback herring (S) Atl. sturgeon (S)	
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA	Short. sturgeon (S) American shad (S) Hickory shad (S)	Atl. sturgeon (S) A Striped bass (S)		Atl. sturgeon (F) A Striped bass (F) G Striped bass (FS) Short. sturgeon (F) American shad (F) Hickory shad (F) Alabama shad (FS) Skipjack herring (FS) Blueback herring (FS) Alewife (S) SB/WB cross (S)	SB/WB cross (F)
FLORIDA	Atl. sturgeon (S) A Striped bass (F) American shad (F) G Striped bass (S) Gulf sturgeon (S)		Alabama shad (S)	Atl. sturgeon (F) Short. sturgeon (F) G Striped bass (F) Hickory shad (FS) Alabama shad (F) Blueback herring (FS) Skipjack herring (F) American shad (S)	SB/WB cross (F)

Table 4.1-6. Question I, LOCATION OF INDUSTRIAL DISCHARGES (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
ALABAMA		Gulf sturgeon (FS) G Striped bass (FS) Short. sturgeon (S) Alabama shad (FS) Skipjack herring (S)		Skipjack herring (F)	SB/WB cross (FS) A Striped bass (S)
MISSISSIPPI				A Striped bass G Striped bass	
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-7. Relative importance of ROAD CONSTRUCTION as a possible contributor to declining anadromous fish stocks within Region 4. S = response by marine representative; F = reponse by freshwater representative; C = response by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA				A Striped bass (FSC) American shad (FSC) Hickory shad (FSC) Alewife (FSC) Blueback herring (FSC) Atl. sturgeon (SC) Short. sturgeon (C)	
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA				All anadromous species (FS)	SB/WB cross (F)
FLORIDA			A Striped bass (F) G Striped bass (F) Atl. sturgeon (S) Alabama shad (S) Gulf sturgeon (S)	Atl. sturgeon (F) Short. sturgeon (F) American shad (FS) Hickory shad (FS) Alabama shad (F) Blueback herring (FS) Skipjack herring (S)	SB/WB cross (F)
ALABAMA		Gulf sturgeon (S) Short. sturgeon (S) G Striped bass (S) Alabama shad (S) Skipjack herring (S)		Gulf sturgeon (F) G Striped bass (F) Alabama shad (F) Skipjack herring (F)	SB/WB cross (FS) A Striped bass (S)

Table 4.1-7. Question I, ROAD CONSTRUCTION (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
MISSISSIPPI				A Striped bass G Striped bass	
LOUISIANA				Atl. sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-8. Relative importance of ACID RAIN as a possible contributor to declining anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA				A Striped bass (FSC) American shad (FSC) Hickory shad (FSC) Alewife (FSC) Blueback herring (FSC) Atl. sturgeon (FSC) Short. sturgeon (SC)	
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA			All anadromous species (F)	All anadromous species (S)	SB/WB cross (F)
FLORIDA			American shad (S) Hickory shad (S) Alabama shad (S) Blueback herring (S)	American shad (F) Hickory shad (F) Alabama shad (F) Blueback herring (F) Atl. sturgeon (FS) Gulf sturgeon (S) Short. sturgeon (F) A Striped bass (F) G Striped bass (F)	SB/WB cross (F)
ALABAMA				Gulf sturgeon (FS) Alabama shad (FS) G Striped bass (FS) Skipjack herring (FS) Short. sturgeon (S)	SB/WB cross A Striped bass (S)
MISSISSIPPI				A Striped bass G Striped bass	

Table 4.1-8. Question I, ACID RAIN (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-9. Question I. Relative importance of CHEMICAL POLLUTION (e.g., heavy metals) as a possible contributor to declining anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA	A Striped bass (F) American shad (F) Hickory shad (F) Alewife (F) Blueback herring (F)			A Striped bass (SC) American shad (SC) Hickory shad (SC) Alewife (SC) Blueback herring (SC) Atl. sturgeon (SC) Short. sturgeon (C)	
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA	Atl. sturgeon (S) Short. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S)			Atl. sturgeon (F) Short. sturgeon (F) A Striped bass (F) G Striped bass (FS) SB/WB cross (S) American shad (F) Hickory shad (F) Alabama shad (FS) Alewife (S) Blueback herring (FS) Skipjack herring (FS)	SB/WB cross (F)
FLORIDA		A Striped bass (F) G Striped bass (F) American shad (F)	Alabama shad (S)	Atl. sturgeon (FS) Short. sturgeon (F) Hickory shad (FS) Alabama shad (F) Blueback herring (FS) Skipjack herring (F) American shad (S) Gulf sturgeon (S)	SB/WB cross (F)

Table 4.1-9. Question I, CHEMICAL POLLUTION (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
ALABAMA				Gulf sturgeon (FS) G Striped bass (FS) Alabama shad (FS) Skipjack herring (FS) Short. sturgeon (S)	SB/WB cross (FS) A Striped bass (S)
MISSISSIPPI				A Striped bass G Striped bass	
LOUISIANA				Atl. sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-10. Question I. Relative importance of THERMAL EFFLUENTS as possible contributors to declining anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA			A Striped bass (S) American shad (S) Hickory shad (S) Alewife (S) Blueback herring (S) Atl. sturgeon (S)	Atl. sturgeon (C) Short. sturgeon (FC) A Striped bass (FC) American shad (FC) Hickory shad (FC) Alewife (SC) Blueback herring (FC)	
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA	Short. sturgeon (S) American shad (S) Hickory shad (S)	Atl. sturgeon (S) A Striped bass (S)	All anadromous species (F)	Skipjack herring (S) G Striped bass (S) SB/WB cross (S) Alabama shad (S) Alewife (S) Blueback herring (S)	SB/WB cross (F)
FLORIDA			A Striped bass (F) G Striped bass (F) American shad (F) Atl. sturgeon (S) Alabama shad (S) Gulf sturgeon (S)	Atl. sturgeon (F) Short. sturgeon (F) Hickory shad (FS) Blueback herring (FS) Skipjack herring (F) American shad (S) Alabama shad (F)	SB/WB cross (F)
ALABAMA				Gulf sturgeon (FS) G Striped bass (FS) Alabama shad (FS) Skipjack herring (FS) Short. sturgeon (S)	SB/WB cross (FS) A Striped bass (S)

4.1-10. Question I, THERMAL EFFLUENTS (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
MISSISSIPPI				A Striped bass G Striped bass	
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass SB/WB cross Alabama shad	

4.1-11. Question I. Relative importance of TURBIDITY as a possible contributor to the decline in anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA		A Striped bass (F) American shad (F) Hickory shad (F) Alewife (F) Blueback herring (F)	Atl. sturgeon (C) Short. sturgeon (C) A Striped bass (C) American shad (C) Hickory shad (C) Alewife (C) Blueback herring (C)	Atl. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S) Alewife (S) Blueback herring (S)	
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA				All anadromous species (FS)	SB/WB cross (F)
FLORIDA			Atl. sturgeon (S) Gulf sturgeon (S) A Striped bass (FS) American shad (S) Alabama shad (S)	Atl. sturgeon (F) Short. sturgeon (F) G Striped bass (F) Hickory shad (FS) Alabama shad (F) Blueback herring (FS) Skipjack herring (F) American shad (S)	SB/WB cross (F)
ALABAMA				Gulf sturgeon (FS) G Striped bass (FS) Alabama shad (FS) Skipjack herring (FS) Short. sturgeon (S)	SB/WB cross (FS) A Striped bass (S)

Table 4.1-11. Question I, TURBIDITY (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
MISSISSIPPI				A Striped bass G Striped bass	
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-12. Question I. Relative importance of LOW OXYGEN LEVELS as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLIN[illegible] POPULATI[illegible]
NORTH CAROLINA		A Striped bass (F) American shad (F) Hickory shad (F) Alewife (FS) Blueback herring (FS)		Atl. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S)	
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA				All anadromous species (FS)	SB/WP [illegible] (F)
FLORIDA		A Striped bass (F) American shad (FS) Hickory shad (S) Blueback herring (S)	G Striped bass (F) Atl. sturgeon (S) Alabama shad (S) Gulf sturgeon (S)	Atl. sturgeon (F) Short. sturgeon (F) Hickory shad (F) Alabama shad (F) Blueback herring (F) Skipjack herring (F)	SB/WB [illegible] (F)
ALABAMA		Gulf sturgeon (S) Short. sturgeon (S) G Striped bass (S) Alabama shad (S) Skipjack herring (S)		Gulf sturgeon (F) G Striped bass (F) Alabama shad (F) Skipjack herring (F)	SB/WB [illegible] (FS) A Striped ba (S)
MISSISSIPPI				A Striped bass G Striped bass	
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-13. Question I. Relative importance of SEWERAGE OUTFALLS as possible contributors to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA		Atl. sturgeon (C) Short. sturgeon (C) A Striped bass (C) American shad (C) Hickory shad (C) Alewife (C) Blueback herring (C)		A Striped bass (FS) American shad (FS) Hickory shad (FS) Alewife (FS) Blueback herring (FS) Atl. sturgeon (S)	
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA				All anadromous species (FS)	SB/WB cross (F)
FLORIDA	A Striped bass (F) American shad (F)	Hickory shad (S) American shad (S) Blueback herring (S)	G Striped bass (F) Atl. sturgeon (S) Alabama shad (S) Gulf sturgeon(S)	Atl. sturgeon (F) Short. sturgeon (F) Hickory shad (F) Alabama shad (F) Blueback herring (F) Skipjack herring (F)	SB/WB cross (F)
ALABAMA		Gulf sturgeon (S) Short. sturgeon (S) G. Striped bass (S) Alabama shad (S) Skipjack herring (S)		Gulf sturgeon (F) G Striped bass (F) Alabama shad (F) Skipjack herring (F)	SB/WB cross (FS) A Striped bas (S)
MISSISSIPPI				A Striped bass G Striped bass	
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-14. Question I. Relative importance of <u>INADEQUATE FISHWAY FACILITIES</u> as a possible contributor to the decline in anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA		American shad (F) Hickory shad (F) Alewife (F) Blueback herring (F)	Short. sturgeon (C) A Striped bass (FSC) Atl. sturgeon (SC) American shad (SC) Hickory shad (SC) Alewife (SC) Blueback herring (SC)		
SOUTH CAROLINA		Atl. sturgeon (S) Short. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S) Blueback herring (S)			
GEORGIA		G Striped bass (F) Alabama shad (F)	Blueback herring (F) Skipjack herring (F) Atl. sturgeon (F) Short. sturgeon (F) A Striped bass (F) American shad (F) Hickory shad (F)	All anadromous species (S)	SB/WB [illegible] (F)
FLORIDA	Gulf sturgeon (S)		A Striped bass (F) G Striped bass (F) American shad (FS) Atl. sturgeon (S) Hickory shad (S) Blueback herring (S)	Atl. sturgeon (F) Short. sturgeon (F) Hickory shad (F) Alabama shad (FS) Blueback herring (F) Skipjack herring (F)	SB/WB cross (F)

Table 4.1-14. Question I, INADEQUATE FISHWAY FACILITIES (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
ALABAMA	Gulf sturgeon (F) G Striped bass (F) Alabama shad (F)	Gulf sturgeon (S) Short. sturgeon (S) G Striped bass (S) Alabama shad (S) Skipjack herring (S)		Skipjack herring (F)	SB/WB cross (FS) A Striped bas (F)
MISSISSIPPI					
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-15 Question I. Relative importance of INADEQUATE CONTROL OF WATER RELEASE from dams and impoundments as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA	Atl. sturgeon (C) Short. sturgeon (C) A Striped bass (C) American shad (C) Hickory shad (C) Alewife (C) Blueback herring (C)	A Striped bass (SF)	Atl. sturgeon (S) American shad (S) Hickory shad (S) Alewife (S) Blueback herring (S)	American shad (F) Hickory shad (F) Alewife (F) Blueback herring (F)	
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA				All anadromous species (FS)	SB/WB [illegible] (F)
FLORIDA			A Striped bass (F) American shad (FS) Atl. sturgeon (S) Hickory shad (S) Blueback herring (S) Gulf sturgeon (S)	Atl. sturgeon (F) Short. sturgeon (F) G Striped bass (F) Hickory shad (F) Alabama shad (FS) Blueback herring (F) Skipjack herring (F)	SB/WB [illegible] (F)
ALABAMA	Gulf sturgeon (F) G Striped bass (F) Alabama shad (F) Skipjack herring (F)				SB/WB cross (FS) A Striped bas (S)
MISSISSIPPI					

Table 4.1-15. Question I, INADEQUATE CONTROL OF WATER RELEASE (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	
TEXAS	G Striped bass				

Table 4.1-16. Question 1. Relative importance of REDUCED FRESHWATER INPUT TO ESTUARIES as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR IN STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA			Short. sturgeon (C) Atl. sturgeon (SC) A Striped bass (SC) American shad (SC) Hickory shad (SC) Alewife (SC) Blueback herring (SC)		
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA			All anadromous species (F)	All anadromous species (S)	SB/WB [illegible] (F)
FLORIDA		American shad (S) Hickory shad (S) Blueback herring (S)	Atl. sturgeon (S)	Gulf sturgeon (S) Atl. sturgeon (F) Short. sturgeon (F) A Striped bass (F) G Striped bass (F) American shad (F) Hickory shad (F) Alabama shad (FS) Blueback herring (F) Skipjack herring (F)	SB/WB [illegible] (F)
ALABAMA			Gulf sturgeon (S) Short. sturgeon (S) G Striped bass (S) Alabama shad (S) Skipjack herring (S)	Gulf sturgeon (F) G Striped bass (F) Alabama shad (F) Skipjack herring (F)	SB/WB cross A Striped ba[illegible] (S)
MISSISSIPPI					

Table 4.1-16. Question I, REDUCED FRESHWATER INPUT TO ESTUARIES (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
LOUISIANA					
				Gulf sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-17. Question I. Relative importance of REDUCTION IN SPAWNING HABITATS as a potential contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATION
NORTH CAROLINA		American shad (F) Hickory shad (F) Alewife (F) Blueback herring (F)	Short. sturgeon (C) Atl. sturgeon (SC) A Striped bass (SC) American shad (SC) Hickory shad (SC) Alewife (SC) Blueback herring (SC)	A Striped bass (F)	
SOUTH CAROLINA		Atl. sturgeon (S) Short. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S) Blueback herring (S)			
GEORGIA	Atl. sturgeon (S) Short. sturgeon (S) American shad (S) Hickory shad (S)	A Striped bass (S)	Skipjack herring (F)	Skipjack herring (S) Blueback herring (FS) Short. sturgeon (F) Atl. sturgeon (F) A Striped bass (F) G Striped bass (FS) American shad (F) Hickory shad (F) Alabama shad (FS) Alewife (S) SB/WB cross (S)	SB/WB [illegible] (F)

Table 4.1-17. Question I, REDUCTION IN SPAWNING HABITATS (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
FLORIDA	A Striped bass (F)	Alabama shad (S)		Atl. sturgeon (F)	SB/WB cross (F)
	American shad (FS)			Short. sturgeon (F)	
	Atl. sturgeon (S)			G Striped bass (F)	
	Hickory shad (S)			Hickory shad (F)	
	Blueback herring (S)			Alabama shad (F)	
	Gulf sturgeon (S)			Blueback herring (F)	
				Skipjack herring (F)	
ALABAMA	Gulf sturgeon (F)			Skipjack herring (FS)	SB/WB cross (FS)
	G Striped bass (F)			G Striped bass (S)	A Striped ba (S)
	Alabama shad (F)			Gulf sturgeon (S)	
				Short. sturgeon (S)	
				Alabama shad (S)	
MISSISSIPPI				A Striped bass	
				G Striped bass	
LOUISIANA				Gulf sturgeon	
				A Striped bass	
				G Striped bass	
				Alabama shad	
				SB/WB cross	

Table 4.1-13. Question I. Relative importance of REDUCTION IN NURSERY AREAS as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA		A Striped bass (F) American shad (F) Hickory shad (F) Alewife (F) Blueback herring (F)	Atl. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S) Alewife (S) Blueback herring (S)	Hickory shad (C) Atl. sturgeon (C) Short. sturgeon (C) A Striped bass (C) American shad (C) Alewife (C) Blueback herring (C)	
SOUTH CAROLINA				All anadromous species (S)	
GEORGIA	Atl. sturgeon (S) American shad (S) Hickory shad (S) Short. sturgeon (S)			Atl. sturgeon (F) Short. sturgeon (F) American shad (F) Hickory shad (F) Alabama shad (FS) Skipjack herring (FS) Blueback herring (FS) A Striped bass (FS) G Striped bass (FS) SB/WB cross (S) Alewife (S)	SB/WB (F)
FLORIDA	A Striped bass (F) American shad (FS) Hickory shad (S) Blueback herring (S)	Atl. sturgeon (S) Gulf sturgeon (S)	Alabama shad (S)	Atl. sturgeon (F) Short. sturgeon (F) G Striped bass (F) Hickory shad (F) Alabama shad (F) Blueback herring(F) Skipjack herring (F)	SB/WB cross (F)

Table 4.1-18. Question I, REDUCTION IN NURSERY AREAS (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
ALABAMA	Gulf sturgeon (F)			Skipjack herring (FS)	
	G Striped bass (F)			Short. sturgeon (S)	SB/WB cross (FS)
	Alabama shad (F)			Gulf sturgeon (S)	
				G Striped bass (S)	A Striped ba (S)
				Alabama shad (S)	

Table 4.1-19. Question 1. Relative importance of POOR FOOD AVAILABILITY as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA		A Striped bass (F) American shad (F) Hickory shad (F) Alewife (F) Blueback herring (F)		Atl. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S) Alewife (S) Blueback herring (S)	
SOUTH CAROLINA			All anadromous species (S)		
GEORGIA	Atl. sturgeon (S) Short. sturgeon (S) American shad (S) Hickory shad (S)	A Striped bass (S)		Skipjack herring (FS) Blueback herring (FS) SB/WB cross (S) A Striped bass (F) G Striped bass (F) American shad (F) Hickory shad (F) Alabama shad (FS) Short. sturgeon (F) Atl. sturgeon (F) Alewife (S)	SB/WB cross (F)
FLORIDA		American shad (S) Hickory shad (S) Blueback herring (S)	A Striped bass (F) G Striped bass (F) Alabama shad (S)	American shad (F) Atl. sturgeon (FS) Short. sturgeon (F) Hickory shad (F) Alabama shad (F) Blueback herring (F) Skipjack herring (F) Gulf sturgeon (S)	SB/WB cross (F)

Table 4.1-19. Question I, POOR FOOD AVAILABILITY (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
ALABAMA		Gulf sturgeon (S) Short. sturgeon (S) G Striped bass (S) Alabama shad (S) Skipjack herring (S)		Gulf sturgeon (F) G Striped bass (F) Alabama shad (F) Skipjack herring (F)	SB/WB cross (FS) A Striped bass (S)
MISSISSIPPI					
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-20. Question I. Relative importance of SPAWNING AREAS TOO ACCESSIBLE TO FISHERMEN as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA		A Striped bass (FC) Atl. sturgeon (C) Short. sturgeon (C) American shad (C) Hickory shad (C) Alewife (C) Blueback herring (C)	Atl. sturgeon (S) Short. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S) Alewife (S) Blueback herring (S)	American shad (F) Hickory shad (F) Alewife (F) Blueback herring (F)	
SOUTH CAROLINA		Short. sturgeon (S)	Atl. sturgeon (S) American shad (S)	A Striped bass (S) American shad (S) Blueback herring (S)	
GEORGIA	Short. sturgeon (S) A Striped bass (S)	American shad (S) Hickory shad (S)	American shad (F) Hickory shad (F) Alabama shad (F) Blueback herring (F) Skipjack herring (F)	A Striped bass (F) G Striped bass (FS) Short. sturgeon (F) Atl. sturgeon (FS) SB/WB cross (S) Alabama shad (S) Alewife (S) Blueback herring (S) Skipjack herring (S)	SB/WB [illegible] (F)
FLORIDA		American shad (S) Hickory shad (S) Blueback herring (S)	A Striped bass (F) G Striped bass (S) American shad (F) Atl. sturgeon (S) Alabama shad (S) Gulf sturgeon (S)	Atl. sturgeon (F) Short. sturgeon (F) Hickory shad (F) Alabama shad (F) Blueback herring (F) Skipjack herring (F)	SB/WB cross (F)

Table 4.1-20. Question I, SPAWNING AREAS TOO ACCESSIBLE TO FISHERMEN (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
ALABAMA			Gulf sturgeon(S) Short. sturgeon (S) Alabama shad (S) Skipjack herring (S)	Gulf sturgeon(F) G Striped bass (F) Alabama shad (F) Skipjack herring (F)	SB/WB cross (FS) A Striped bass (S)
MISSISSIPPI					
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-21. Question 1. Relative importance of <u>POOR WATER QUALITY</u> as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
NORTH CAROLINA	A Striped bass (FC) American shad (FC) Hickory shad (FC) Alewife (FC) Blueback herring (FC)	A Striped bass (S) Alewife (S) Blueback herring (S)		Short. sturgeon (C) Atl. sturgeon (SC) American shad (S) Hickory shad (S)	
SOUTH CAROLINA		Atl. sturgeon (S) Short. sturgeon (S) A Striped bass (S) American shad (S) Hickory shad (S) Blueback herring (S)			
GEORGIA	American shad (S) Atl. sturgeon (S) Short. sturgeon (S) A Striped bass (S) Hickory shad (S)			American shad (F) Hickory shad (F) Atl. sturgeon (F) Short. sturgeon (F) A Striped bass (F) G Striped bass (FS) SB/WB cross (S) Alabama shad (FS) Alewife (S) Blueback herring (FS) Skipjack herring (FS)	SB/WB cross (F)
FLORIDA	Atl. sturgeon (S)	A Striped bass (F) American shad (FS) Hickory shad (S) Blueback herring (S) Gulf sturgeon (S)	G Striped bass (F)	Atl. sturgeon (F) Short. sturgeon (F) Hickory shad (F) Alabama shad (FS) Blueback herring (F) Skipjack herring (F)	SB/WB cross (F)

Table 4.1-21. Question I, POOR WATER QUALITY (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION	NO DECLINING POPULATIONS
ALABAMA	Gulf sturgeon(S) Short. sturgeon (S) G Striped bass (S) Alabama shad (S) Skipjack herring (S)	Gulf sturgeon (F) G Striped bass (F) Alabama shad (F)		Skipjack herring (F)	SB/WB cross (FS) A Striped bass (S)
MISSISSIPPI	G Striped bass Gulf sturgeon				
LOUISIANA				Gulf sturgeon A Striped bass G Striped bass Alabama shad SB/WB cross	

Table 4.1-22. Question I. Relative importance of OTHER DISTURBANCES as possible contributors to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	POTENTIAL CONTRIBUTOR	VERY IMPORTANT	IMPORTANT	NOT A CONTRIBUTOR TO STOCK DECLINE	INADEQUATE INFORMATION
FLORIDA	Agricultural Drainage	A Striped bass (F) American shad (F)			Atl. sturgeon (F) Short. sturgeon (F) G Striped bass (F) Hickory shad (F) Alabama shad (F) Blueback herring (F) Skipjack herring (F)
	Non-Point Source Pollutants	Atl. sturgeon (S) American shad (S) Hickory shad (S)			Alabama shad (S) Blueback herring (S) Gulf sturgeon
	Proposed Phosphate Strip-mining	Gulf sturgeon (S)		Atl. sturgeon (S) American shad (S) Hickory shad (S) Alabama shad (S) Blueback herring (S)	
	Overfishing	Atl. sturgeon (S) American shad (S)	Gulf sturgeon (S)		Hickory shad (S) Alabama shad (S) Blueback herring (S)
GEORGIA	Commercial Overfishing				All anadromous species (F)

Table 4.1-23. Question II. Relative importance of CHANNELIZATION as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Albemarle Sound tributaries (F) Chowan (F) Tar (F) Neuse (F) Cape Fear (FC) Northeast Cape Fear (F) New (S)	Roanoke (F)	Pee Dee (F) Albemarle Sound (S) North (S) Newport (S) White Oak (S) Currituck Sound (S) Roanoke (C) Chowan (C) Neuse (C)	Chowan (S) Roanoke (S) Albemarle area rivers (S) Pungo (S) Pamlico (S) Tar (S) Neuse (S) Trent (S) Cape Fear (S) Northeast Cape Fear (S) Black (S)
SOUTH CAROLINA				All river systems (S)
GEORGIA	Ogeechee (S) Altamaha (S) Satilla (S)			Savannah (S) St. Marys (S) All river systems (S)
FLORIDA	St. Johns (F) Apalachicola (FS)	St. Johns (S) St. Marys (S)	Nassau (F) St. Marys (F) Tomoka (S) Suwannee (S) Ochlockonee (F)	Hillsborough (S)
ALABAMA				All river systems
MISSISSIPPI				All river systems
LOUISIANA	Pearl, Bayou LaCombe, Tchefuncte, Tangipahoa, Tickfaw, Amite, Mississippi,			Vermillion, Calcasieu, Sabine

Table 4.1-24 Question II. Relative importance of DREDGE AND FILL PROJECTS as possible contributors to the decline of anadromous fish stocks in Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Albemarle Sound tributaries (F) Chowan (F)	Roanoke (F)	All river systems (S) Tar (F), Neuse (F) Northeast Cape Fear (F) Pee Dee (F)	Roanoke (C) Chowan (C) Neuse (C) Cape Fear (C)
SOUTH CAROLINA				All river systems (S)
GEORGIA	Savannah (S) Ogeechee (S) Altamaha (S) St. Marys (S)		Ogeechee (F) Satilla (F) St. Marys (F)	Savannah (F) Altamaha (F) Apalachicola (F)
FLORIDA	St. Johns (F) Apalachicola (F)	St. Johns (S)	Tomoka (S) Suwannee (S) Apalachicola (S) Nassau (F) St. Marys (F) Ochlockonee (F)	St. Marys (S) Hillsborough (S)
ALABAMA				All river systems (FS)
MISSISSIPPI				All river systems
LOUISIANA	Mississippi Atchafalaya Mermentau			Pearl, Bayou LaCombe, Tchefuncte, Tangipahoa, Tickfaw, Amite, Vermillion, Calcasieu, Sabine

Table 4.1-25. Question II. Relative importance of BULKHEADING as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Albemarle Sound tributaries (F) Chowan (F)		All river systems (S) Roanoke (F) Tar (F) Neuse (F) Cape Fear (F) Northeast Cape Fear (F) Pee Dee (F)	Roanoke (C) Chowan (C) Neuse (C) Cape Fear (C)
SOUTH CAROLINA				All river systems (S)
GEORGIA			Apalachicola (F) Altamaha (F) Satilla (F) St. Marys (F)	Savannah (F) Ogeechee (F) All river systems (S)
FLORIDA		St. Johns (F) Nassau (F) St. Marys (F) Apalachicola (F)	Ochlockonee (F) Tomoka (F) Hillsborough (S) Suwannee (S) Apalachicola (S)	St. Marys (S) St. Johns (S)
ALABAMA		Alabama (F) Tennessee (F)		All river systems (S) Tombigbee (F) Coosa (F) Tallapoosa (F)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-2? Question II. Relative importance of DAMS AND IMPOUNDMENTS as possible contributors to the decline of anadromous fish stocks in Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Roanoke (C) Neuse (C)	Roanoke (F) Tar (F) Neuse (F) Cape Fear (F) Pee Dee (F)	All river systems except Cape Fear (S) Albemarle Sound trib. (F) Chowan (FC) Northeast Cape Fear (F) Cape Fear (C)	Cape Fear (S)
SOUTH CAROLINA		Pee Dee (S) Santee (S) Cooper (S) Savannah (S)	Waccamaw (S) Black (S) Sampit (S) Ashley (S) Edisto (S) Ashepoo (S) Combahee (S)	
GEORGIA	Apalachicola (F) Savannah (S) Ogeechee (S) Altamaha (S) Satilla (S) St. Marys (S)		Ogeechee (F) Satilla (F) St. Marys (F)	Savannah (F) Altamaha (F)
FLORIDA	St. Johns (F) Hillsborough (S) Apalachicola (S)		St. Marys (FS) Nassau (F) St. Johns (S) Tomoka (S) Suwannee (S)	Apalachicola (F) Ochlockonee (F)

Table 4.1-26. Question II, DAMS AND IMPOUNDMENTS (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
ALABAMA	Alabama (FS) Tombigbee (FS) Tennessee (F) Coosa (F) Tallapoosa (F)		Perdido (S) Fish (S) Magnolia (S) Bon Secour (S) Dog (S) Fowl (S)	
MISSISSIPPI				All river systems
LOUISIANA	Pearl, Bayou LaCombe, Mermentau			All other river systems

Table [illegible]-17. Question 11. Relative importance of INDUSTRIAL WATER INTAKES as possible contributors to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Cape Fear (F)	Chowan (C) Roanoke (FC) Tar (F) Neuse (FC) Pee Dee (F) Cape Fear (C)	Currituck Sound (S) Northeast Cape Fear (F)	All river systems except Currituck Sound (S) Albemarle Sound trib. (F) Chowan (F)
SOUTH CAROLINA				All river systems (S)
GEORGIA			Ogeechee (F) Satilla (F) St. Marys (F)	All river systems (S) Savannah (F) Altamaha (F) Apalachicola (F)
FLORIDA		Nassau (F) St. Marys (F) St. Johns (F)	Apalachicola (FS) St. Johns (F) Ochlockonee (F) St. Marys (S) Hillsborough (S) Suwannee (S)	Tomoka (S)
ALABAMA			All river systems (S)	All river systems (F)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-28. Question II. Relative importance of LOCATION OF INDUSTRIAL DISCHARGES as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Chowan (FC) Roanoke (FC) Tar (F) Neuse (FC) Cape Fear (F)	Pee Dee (F) Cape Fear (C)	Northeast Cape Fear (F) Currituck Sound (S)	Albemarle Sound trib. (F) All river systems except Currituck Sound (S)
SOUTH CAROLINA				All river systems (S)
GEORGIA	Ogeechee (S) Satilla (S)	Savannah (S) Altamaha (S) St. Marys (S)	Satilla (F) St. Marys (F)	Apalachicola (F) Savannah (F) Ogeechee (F) Altamaha (F)
FLORIDA	St. Johns (F) Nassau (F) St. Marys (F) Suwannee (S)	Apalachicola (FS) St. Johns (S) Hillsborough (S)	Ochlockonee (F) Tomoka (S)	St. Marys (S)
ALABAMA	Perdido (S) Alabama (S) Tombigbee (S) Bon Secour (S)	All river systems (F)	Fish (S) Magnolia (S) Dog (S) Fowl (S)	
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-29. Question II. Relative importance of ROAD CONSTRUCTION as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA			Currituck Sound (S)	All other river systems (S) All river systems (FC)
SOUTH CAROLINA				All river systems (S)
GEORGIA				All river systems (FS)
FLORIDA			All other river systems (F) Hillsborough (S) Suwannee (S) Apalachicola (S)	St. Johns (FS) St. Marys (S) Tomoka (S)
ALABAMA				All river systems (FS)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-30. Question II. Relative importance of <u>ACID RAIN</u> as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA				All river systems (FSC)
SOUTH CAROLINA				All river systems (S)
GEORGIA			All river systems (F)	All river systems (S)
FLORIDA			All river systems (S)	All river systems (F)
ALABAMA				All river systems (FS)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-31. Question II. Relative importance of <u>CHEMICAL POLLUTION</u> (e.g., heavy metals) as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Albemarle Sound tributaries (F)	Chowan (S)	Other Albemarle area rivers (S)	Roanoke (SC)
	Chowan (F)		Pungo (S)	Albemarle Sound (S)
	Roanoke (F)		Pamlico (S)	Neuse (SC)
	Tar (F)		Tar (S)	Cape Fear (SC)
	Neuse (F)		Trent (S)	Northeast Cape Fear (S)
	Cape Fear (F)		North (S)	Chowan (C)
	Northeast Cape Fear (F)		Newport (S)	
	Pee Dee (F)		White Oak (S)	
			New (S)	
			Black (S)	
			Currituck Sound (S)	
SOUTH CAROLINA		Sampit (S)		Waccamaw (S)
				Pee Dee (S)
				Black (S)
				Santee (S)
				Ashley (S)
				Edisto (S)
				Ashepoo (S)
				Combahee (S)
				Savannah (S)
				Cooper (S)
GEORGIA	Savannah (S)		Satilla (F)	Ogeechee (FS)
	Altamaha (S)		St. Marys (F)	Satilla (S)
				St. Marys (S)
				Savannah (F)
				Altamaha (F)
				Apalachicola (F)

Table 4.1-31. Question II, CHEMICAL POLLUTION (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
FLORIDA	Nassau (F) St. Marys (F)	St. Johns (FS) Apalachicola (F) St. Marys (S) Tomoka (S)	Ochlockonee (F)	Hillsborough (S) Suwannee (S) Apalachicola (S)
ALABAMA	Perdido (S) Alabama (S) Tombigbee (S)	All river systems (F)	Fish (S) Magnolia (S) Bon Secour (S) Dog (S) Fowl (S)	
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-32. Question II. Relative importance of THERMAL EFFLUENTS as possible contributors to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA			All river systems (S) All river systems except Pee Dee (F)	Pee Dee (F) All river systems (C)
SOUTH CAROLINA			Waccamaw (S) Black (S) Sampit (S) Santee (S) Ashley (S) Ashepoo (S) Combahee (S)	Pee Dee (S) Cooper (S) Savannah (S) Edisto (S)
GEORGIA			All river systems (F)	All river systems (S)
FLORIDA		St. Johns (S)	All river systems (F) Tomoka (S) Hillsborough (S) Suwannee (S) Apalachicola (S)	St. Marys (S)
ALABAMA				All river systems (FS)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-33. Question II. Relative importance of TURBIDITY as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = reponse by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA		Chowan (F) Roanoke (F) Tar (F) Neuse (F) Cape Fear (F) Northeast Cape Fear (F) Pee Dee (F)	Pungo (S) North (S) Newport (S) White Oak (S) New (S) Black (S) Currituck Sound (S) Albemarle Sound tributaries (F) Cape Fear (C) Roanoke (C) Chowan (C) Neuse (C)	Chowan (S) Albemarle Sound (S) Other Albemarle area rivers (S) Pamlico (S) Tar (S) Neuse (S) Trent (S) Cape Fear (S) Northeast Cape Fear (S) Roanoke (S)
SOUTH CAROLINA			All river systems (S)	
GEORGIA			Ogeechee (F) Satilla (F) St. Marys (F)	Apalachicola (F) Savannah (F) Altamaha (F) All river systems (S)
FLORIDA		Apalachicola (F)	St. Johns (F) Nassau (F) St. Marys (F) Ochlockonee (F) Suwannee (S)	St. Marys (S) St. Johns (S) Tomoka (S) Hillsborough (S) Apalachicola (S)
ALABAMA				All river systems (FS)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-34. Question II. Relative importance of LOW OXYGEN LEVELS as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Chowan (SC) Roanoke (S) Neuse (C)	Albemarle Sound (S) Albemarle Sound tributaries (F) Chowan (F) Roanoke (F) Tar (F) Neuse (F) Cape Fear (F) Northeast Cape Fear (F) Pee Dee (F)	Pungo (S) North (S) Newport (S) White Oak (S) Black (S) Roanoke (C) Cape Fear (C)	Other Albemarle area rivers (S) Pamlico (S) Tar (S) Neuse (S) Trent (S) New (S) Cape Fear (S) Northeast Cape Fear (S) Currituck Sound (S)
SOUTH CAROLINA				All river systems (S)
GEORGIA			Ogeechee (F)	Apalachicola (F) Savannah (F) Altamaha (F) Satilla (F) St. Marys (F) All river systems (S)
FLORIDA	St. Johns (F)	St. Johns (S)	Nassau (F) St. Marys (F) Apalachicola (FS) Ochlockonee (F) Suwannee (S)	St. Marys (S) Tomoka (S) Hillsborough (S)

Table 4.1-34. Question II, LOW OXYGEN LEVELS (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
ALABAMA	Perdido (S) Alabama (S) Tombigbee (S)		Fish (S) Magnolia (S) Bon Secour (S) Dog (S) Fowl (S)	All river systems (F)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-35. Question 11. Relative importance of SEWERAGE OUTFALLS as possible contributors to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Roanoke (C) Chowan (C) Neuse (C)	Albemarle Sound tributaries (F) Chowan (F) Roanoke (F) Tar (F) Neuse (F) Cape Fear (FC) Northeast Cape Fear (F) Pee Dee (F)	Albemarle Sound (S) Pungo (S) Pamlico (S) North (S) Black (S) Currituck Sound (S)	Chowan (S) Roanoke (S) Other Albemarle area rivers (S) Tar (S) Neuse (S) Trent (S) Newport (S) White Oak (S) New (S) Cape Fear (S) Northeast Cape Fear (S)
SOUTH CAROLINA				All river systems (S)
GEORGIA			Ogeechee (F) Altamaha (F) Satilla (F) St. Marys (F)	All river systems (S) Savannah (F) Apalachicola (F)
FLORIDA	St. Johns (F) Hillsborough (S)	Apalachicola (FS)	Nassau (F) St. Marys (F) Ochlockonee (F) Tomoka (S) Suwannee (S)	St. Marys (S) St. Johns (S)
ALABAMA				All river systems (FS)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-36. Question II. Relative importance of INADEQUATE FISHWAY FACILITIES as possible contributors to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA		Neuse (C)	Chowan (SC)	Neuse (S)
		Cape Fear (C)	Roanoke (SC)	Cape Fear (SF)
			Albemarle Sound (S)	Albemarle Sound tributaries (F)
			Other Albemarle area rivers (S)	Chowan (F)
			Pungo (S)	Roanoke (F)
			Pamlico (S)	Tar (F)
			Tar (S)	Neuse (F)
			Trent (S)	Northeast Cape Fear (F)
			North (S)	Pee Dee (F)
			Newport (S)	
			White Oak (S)	
			New (S)	
			Northeast Cape Fear (S)	
			Black (S)	
			Currituck Sound (S)	
SOUTH CAROLINA	Santee (S)	Pee Dee (S)	Waccamaw (S)	
		Savannah (S)	Black (S)	
			Sampit (S)	
			Cooper (S)	
			Ashepoo (S)	
			Combahee (S)	
			Ashley (S)	
			Edisto (S)	
GEORGIA			All river systems (F)	All river systems (S)
FLORIDA	Hillsborough (S)		St. Johns (F)	St. Johns (S)
	Apalachicola (S)		Nassau (F)	St. Marys (S)
			St. Marys (F)	
			Apalachicola (F)	
			Ochlockonee (F)	
			Suwannee (S)	
			Tomoka (S)	

Table 4.1-36. Question II, INADEQUATE FISHWAY FACILITIES (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
ALABAMA	Alabama (F) Tombigbee (F) Tennessee (F) Tallapoosa (F) Coosa (F)			All river systems (S)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-37. Question II. Relative importance of INADEQUATE CONTROL OF WATER RELEASE from dams and impoundments as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Roanoke (C)	Roanoke (FS) Tar (F) Neuse (F) Cape Fear (F) Pee Dee (F)	Neuse (C) All river systems except Roanoke (S) Albemarle Sound tributaries (F) Chowan (FSC) Northeast Cape Fear (F) Cape Fear (SC)	
SOUTH CAROLINA			Waccamaw (S) Black (S) Sampit (S) Ashley (S) Edisto (S) Ashepoo (S) Combahee (S)	Pee Dee (S) Santee (S) Cooper (S) Savannah (S)
GEORGIA			Ogeechee (F) Satilla (F) St. Marys (F)	Apalachicola (F) Savannah (F) Altamaha (F) All river systems (S)
FLORIDA			St. Johns (FS) Nassau (F) St. Marys (FS) Hillsborough (S) Suwannee (S) Apalachicola (S) Tomoka (S)	Apalachicola (F) Ochlockonee (F)

Table 4.1-37. Question II, INADEQUATE CONTROL OF WATER RELEASE (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
ALABAMA	Tombigbee (F) Coosa (F) Tallapoosa (F)	Alabama (FS) Tennessee (F) Tombigbee (S)	Perdido (S) Fish (S) Magnolia (S) Bon Secour (S) Dog (S) Fowl (S)	
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-38. Question II. Relative importance of REDUCED FRESHWATER INPUT TO ESTUARIES as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Chowan (C)		All river systems (S) Roanoke (C) Neuse (C) Cape Fear (C)	All river systems (F)
SOUTH CAROLINA				All river systems (S)
GEORGIA			All river systems (F)	All river systems (S)
FLORIDA		St. Johns (S)	Tomoka (S) Hillsborough (S) Suwannee (S) Apalachicola (S)	St. Marys (S) All river systems (F)
ALABAMA			All river systems (S) All river systems except Tombigbee (F)	Tombigbee (F)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-39 Question II. Relative importance of REDUCTION IN SPAWNING HABITATS as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	New (S) Albemarle Sound tributaries (F) Chowan (FC) Roanoke (F) Tar (F) Neuse (F) Cape Fear (F) Northeast Cape Fear (F)		All river systems except New River (S) Pee Dee (F) Roanoke (C) Neuse (C) Cape Fear (C)	
SOUTH CAROLINA	Santee (S)	Pee Dee (S) Cooper (S) Savannah (S)		Waccamaw (S) Black (S) Sampit (S) Ashley (S) Edisto (S) Ashepoo (S) Combahee (S)
GEORGIA	Apalachicola (F) Savannah (S) Ogeechee (S) Altamaha (S) Satilla (S) St. Marys (S)		Ogeechee (F) Satilla (F) St. Marys (F)	Savannah (F) Altamaha (F)
FLORIDA	St. Johns (F) Hillsborough (S) Apalachicola (S)	St. Johns (S)	Nassau (F) St. Marys (F) Tomoka (S) Suwannee (S)	Apalachicola (F) Ochlockonee (F) St. Marys (S)

Table 4.1-39. Question II, REDUCTION IN SPAWNING HABITATS (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
ALABAMA		Alabama (F) Tennessee (F) Tombigbee (F) Coosa (F) Tallapoosa (F)		All river systems (S)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-40. Question II. Relative importance of REDUCTION IN NURSERY AREAS as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Albemarle Sound tributaries (F) Chowan (FC) Roanoke (F) Tar (F) Neuse (F) Cape Fear (F) Northeast Cape Fear (F) New (S)		All river systems except New River (S) Pee Dee (F) Roanoke (C) Neuse (C) Cape Fear (C)	
SOUTH CAROLINA	Santee (S)	Pee Dee (S) Cooper (S) Savannah (S)		Waccamaw (S) Black (S) Sampit (S) Ashley (S) Edisto (S) Ashepoo (S) Combahee (S)
GEORGIA	Savannah (S) Ogeechee (S) Altamaha (S) Satilla (S) St. Marys (S)		Ogeechee (F) Satilla (F) St. Marys (F)	Savannah (F) Altamaha (F) Apalachicola (F)
FLORIDA	St. Johns (F)	Nassau (F) St. Marys (F) St. Johns (S) Hillsborough (S) Apalachicola (S)	Ochlockonee (F) Tomoka (S) Suwannee (S)	Apalachicola (F) St. Marys (S)

Table 4.1-40. Question II, REDUCTION IN NURSERY AREAS (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
ALABAMA		Alabama (F)		Alabama (S)
		Tennessee (F)		Perdido (S)
		Tombigbee (F)		Tombigbee (S)
		Coosa (F)		Fish (S)
		Tallapoosa (F)		Magnolia (S)
				Bon Secour (S)
				Dog (S)
				Fowl (S)
MISSISSIPPI				Pascagoula
				Tchouticabouffa
				Biloxi
				Wolf
				Jourdan
				Pearl
LOUISIANA				All river systems

Table 4.1-41. Relative importance of POOR FOOD AVAILABILITY as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA		Albemarle Sound tributaries (F) Chowan (F) Roanoke (F) Tar (F) Neuse (F) Cape Fear (F) Northeast Cape Fear (F)	Roanoke (C) Neuse (C) Cape Fear (C)	Pee Dee (F) All river systems (S) Chowan (C)
SOUTH CAROLINA				All river systems (S)
GEORGIA		Savannah (S) Ogeechee (S) Altamaha (S) Satilla (S) St. Marys (S)		All river systems (F)
FLORIDA			Ochlockonee (F)	St. Johns (FS) St. Marys (FS) Apalachicola (FS) Nassau (F) Tomoka (S) Hillsborough (S) Suwannee (S)
ALABAMA				All river systems (FS)
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-42. Question II. Relative importance of SPAWNING AREAS BEING TOO ACCESSIBLE TO FISHERMEN as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Roanoke (C)	Albemarle Sound tributaries (S) Chowan (F) Roanoke (F) Tar (F) Neuse (F) Cape Fear (F) Northeast Cape Fear (F)	All river systems (S) Chowan (C) Neuse (C) Cape Fear (C)	Pee Dee (F)
SOUTH CAROLINA			All river systems (S)	
GEORGIA				All river systems (FS)
FLORIDA		St. Johns (S)	St. Johns (F) Nassau (F) St. Marys (FS) Apalachicola (FS) Ochlockonee (F) Tomoka (S) Hillsborough (S) Suwannee (S)	
ALABAMA			Alabama (S) Perdido (S) Tombigbee (S) Fish (S) Magnolia (S) Bon Secour (S) Dog (S) Fowl (S)	Alabama (F) Tennessee (F) Tombigbee (F) Coosa (F) Tallapoosa (F)

Table 4.1-41. Question 11, SPAWNING AREAS BEING TOO ACCESSIBLE TO FISHERMEN (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
MISSISSIPPI				All river systems
LOUISIANA				All river systems

Table 4.1-43. Question II. Relative importance of POOR WATER QUALITY as a possible contributor to the decline of anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
NORTH CAROLINA	Albemarle Sound (S) Albemarle Sound tributaries (F) Chowan (FSC) Roanoke (FSC) Tar (F) Neuse (FC) Cape Fear (S)	Northeast Cape Fear (F) Pee Dee (F) Other Albemarle area rivers (S)	Pungo (S) North (S) Newport (S) White Oak (S) Black (S)	Pamlico (S) Tar (S) Neuse (S) Trent (S) New (S) Cape Fear (SC) Northeast Cape Fear (S) Currituck Sound (S)
SOUTH CAROLINA		Sampit (S) Savannah (S)		Waccamaw (S) Black (S) Santee (S) Ashepoo (S) Combahee (S) Pee Dee (S) Edisto (S) Cooper (S) Ashley (S)
GEORGIA	Savannah (S) Ogeechee (S) Altamaha (S) Satilla (S) St. Marys (S)		Ogeechee (F) Satilla (F) St. Marys (F)	Savannah (F) Altamaha (F) Apalachicola (F)
FLORIDA	Nassau (F) St. Marys (F) Hillsborough (S)	St. Johns (FS) Apalachicola (F) Tomoka (S)	Ochlockonee (F) Suwannee (S) Apalachicola (S)	St. Marys (S)

Table 1.4-43. Question II, POOR WATER QUALITY (cont'd.).

STATE	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
ALABAMA		Tombigbee (FS) Coosa (F) Tallapoosa (F) Perdido (S) Alabama (S)	Fish (S) Magnolia (S) Bon Secour (S) Dog (S) Fowl (S)	Alabama (F) Tennessee (F)
MISSISSIPPI				
LOUISIANA				Pearl, Bayou LaCombe, Tchefuncte, Tangipahoa, Tickfaw, Amite, Mississippi, Atchafalaya, Vermillion, Mermentau, Calcasieu, Sabine

Table 4.1-44. Question II. OTHER DISTURBANCES which may be possible contributors to declining anadromous fish stocks within Region 4. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

STATE	POTENTIAL CONTRIBUTOR	VERY IMPORTANT	IMPORTANT	DOES NOT CONTRIBUTE TO DECLINING STOCKS	INADEQUATE INFORMATION
FLORIDA	Agricultural Drainage	St. Johns (F)			
	Non-Point Sources (agricultural and domestic)		St. Johns (S) Tomoka (S) Suwannee (S)	Hillsborough (S)	St. Marys (S) Apalachicola (S)
	Proposed Phosphate Strip-Mining	Suwannee (S)	Hillsborough (S)	St. Marys (S) St. Johns (S) Tomoka (S) Apalachicola (S)	
	Overfishing	St. Johns (S) Hillsborough (S)	Apalachicola (S)	Suwannee (S)	St. Marys (S) Tomoka (S)
GEORGIA	Commercial Overfishing				All river systems (F)
NORTH CAROLINA	Locks and Barriers		Neuse (C) Cape Fear (C)	Roanoke (C) Chowan (C)	

Table 4.1-45. Questionnaire responses by State, Federal, and other agencies concerning management practices for anadromous fishes in the Southeastern United States. S = response by marine representative; F = response by freshwater representative; C = responses by other agencies.

QUESTION	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	MISSISSIPPI	LOUISIANA
III. Indicate the relative importance of the following categories as they pertain to DECLINING ANADROMOUS FISH STOCKS in your State							
A. FISHERIES MANAGEMENT							
1. Overfishing within State waters	Important (F) Does not contribute (S) Inadequate information (C)	Important (F) Inadequate information (S)	Important (S) Inadequate information (F)	Very important (S) Does not contribute (F)	Inadequate information (FS)	Does not contribute	Inadequate information
2. Competition by other species	Does not contribute (FS) Inadequate information (C)	Does not contribute (FS)	Inadequate information (FS)	Important (S) Does not contribute (F)	Inadequate information (FS)	Does not contribute	Inadequate information
3. Overabundance of natural predators.	Does not contribute (FS) Inadequate information (C)	Does not contribute (F) Inadequate information (S)	Inadequate information (FS)	Does not contribute (FS)	Does not contribute (S) Inadequate information (F)	Does not contribute	Very Important
4. Decline in egg viability	Very important (FSC)	Inadequate information (FS)	Inadequate information (FS)	Does not contribute (F) Inadequate information (S)	Inadequate information (FS)	Does not contribute	Inadequate information
5. Exploitation of parental stocks by other states or countries (international waters)	Very important (FS) Important (C)	Does not contribute (F) Inadequate information (S)	Inadequate information (FS)	Does not contribute (F) Important (S)	Does not contribute (S) Inadequate information (F)	Does not contribute	Does not contribute
6. OTHER (specify)	Excessive water discharge in spring (C)						

Table 4.1-45. Questionnaire responses (cont'd.).

QUESTION	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	MISSISSIPPI	LOUISIANA
III. (cont'd)							
B. REGULATORY ASPECTS							
1. Lack of coordinated effort between STATE and FEDERAL agencies	Does not contribute (FS) Very important (C)	Does not contribute (SF)	Important (FS)	Does not contribute (FS)	Does not contribute (FS)	Does not contribute	Does not contribute
2. Lack of coordinated effort between agencies of BORDERING STATES	Does not contribute (FS) Very important (C)	Important (S) Does not contribute (F)	Important (FS)	Does not contribute (FS)	Does not contribute (FS)	Does not contribute	Does not contribute
3. Lack of coordinated effort among agencies WITHIN YOUR STATE	Does not contribute (FS) Very important (C)	Important (S) Does not contribute (F)	Important (S) Does not contribute (F)	Important (S) Does not contribute (F)	Does not contribute (FS)	Does not contribute	Does not contribute
4. Lack of funding to DEVELOP NEW management programs	Very important (FC) Does not contribute (S)	Important (F) Does not contribute (S)	Inadequate information (S) Very important (F)	Very important (S) Does not contribute (F)	(Very) important (FS)	Important	Does not contribute
5. Lack of funding to MAINTAIN CURRENT management programs	Very important (F) Does not contribute (SC)	Important (F) Does not contribute (S)	Important (FS)	Does not contribute (FS)	(Very) important (FS)	Important	Does not contribute
6. INTERNATIONAL agreements for territorial fishing rights protecting the offshore spawning stock etc...	Inadequate information (F) Do not contribute (S) Adequate (C)	Inadequate information (F) Adequate (S)	Inadequate information (FS)	Do not contribute (FS)	Adequate (FS)	Do not contribute	Adequate
7. FEDERAL laws, regulations and policies are ...	Too many (F) Do not contribute (S) Adequate (C)	Adequate (S) Inadequate (F)	Adequate (S) Inadequate information (F)	Do not contribute (FS)	Adequate (FS)	Do not contribute	Adequate

Table 4.1-45. Questionnaire responses (cont'd).

QUESTION	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	MISSISSIPPI	LOUISIANA
III (cont'd)							
REGULATORY ASPECTS (cont'd)							
8. STATE laws, regulations and policies are ...	Adequate (F) Inadequate (C) Do not contribute (S)	Inadequate (S) Important (F)	Inadequate information (FS)	Inadequate and important (S) Do not contribute (F)	Adequate (FS)	Do not contribute	Adequate
9. LOCAL laws, regulations and policies are ...	Too many (F) Inadequate (C) Do not contribute (S)	Do not contribute (FS)	Adequate but do not contribute (F)	Do not contribute (FS)	Adequate (FS)	Do not contribute	Adequate
10. Other regulatory aspects:	Lack of effort to obtain available funds (C)						

Table 4.1-45. Questionnaire responses (cont'd.).

QUESTION	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	MISSISSIPPI	LOUISIANA
IV. GOALS AND POLICIES							
1. Indicate which species have (or had) spawning runs in your state.	Atl. sturgeon Short. sturgeon A Striped bass Amer. shad Hickory shad Alewife Blueback herring	Atl. sturgeon Short. sturgeon A Striped bass Amer. shad Hickory shad Alewife Blueback herring	Atl. sturgeon Short. sturgeon A Striped bass Amer. shad Hickory shad Alabama shad Blueback herring Skipjack herring G Striped bass	Atl. sturgeon Short. sturgeon A Striped bass G Striped bass Amer. shad Hickory shad Alabama shad Blueback herring Skipjack herring Gulf sturgeon SB/WB cross	Gulf sturgeon Short. sturgeon A striped bass G Striped bass Alabama shad Skipjack herring Alabama shovelnose sturgeon SB/WB cross	Gulf sturgeon A Striped bass G Striped bass	Gulf sturgeon A Striped bass G Striped bass Skipjack herring Alabama shad
2. List species present in your state but NOT PRESENTLY INCLUDED in a fishery management plan.	American shad Hickory shad Blueback herring Alewife Atlantic sturgeon	Atl. sturgeon Short. sturgeon A Striped bass Amer. shad Hickory shad Alewife Blueback herring	Atl. sturgeon Short. sturgeon G Striped bass Alabama shad Alewife Skipjack herring SB/WB cross	Atl. sturgeon Short. sturgeon A Striped bass G Striped bass Amer. shad Hickory shad Alabama shad Blueback herring Skipjack herring	Gulf sturgeom Short. sturgeon A Striped bass G Striped bass Alabama shad Skipjack herring SB/WB cross	Gulf sturgeon A Striped bass G Striped bass	Gulf sturgeon Alabama shad Skipjack herring
3. List species present in your state which will PROBABLY BE INCLUDED in future management plans.	Atl. sturgeon Short. sturgeon A Striped bass Amer. shad Hickory shad Alewife Blueback herring	Atl. sturgeon Short. sturgeon A Striped bass Amer. shad Hickory shad Blueback herring SB/WB cross	A Striped bass Amer. shad Hickory shad	A Striped bass G Striped bass Gulf sturgeon	Gulf sturgeon A Striped bass G Striped bass Alabama shad Skipjack herring SB/WB cross	Gulf sturgeon A Striped bass G Striped bass	Gulf sturgeon G Striped bass
4. List species included on STATE LIST of endangered or threatened species.	Short. sturgeon	Short. sturgeon	Short. sturgeon	Short. sturgeon	Gulf sturgeon Alabama shovelnose sturgeon	None	None

Table 4.1-45. Questionnaire responses (cont'd.).

QUESTION	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	MISSISSIPPI	LOUISIANA
IV GOALS AND POLICIES (cont'd)							
5. List species which provide an annual COMMERCIAL HARVEST.	Atl. sturgeon A Striped bass Amer. shad Hickory shad Alewife Blueback herring	Atl. sturgeon Amer. shad Hickory shad Blueback herring	Atl. sturgeon Amer. shad Hickory shad	Atl. sturgeon Amer. shad Hickory shad Blueback herring Gulf sturgeon	None	None	Skipjack herring
6. List species presently managed for OPTIMUM YIELD.	None	None	None	SB/WB cross	None	None	None
7. Do you restrict the COMMERCIAL fishing effort, during spawning season, for any of these species? Which species?	Yes A Striped bass	Yes Amer. shad Hickory shad Blueback	Yes[1] Atl. sturgeon Amer. shad Hickory shad	Yes Atl. sturgeon Amer. shad Blueback herring Gulf sturgeon	No in saltwater, Yes[2] in freshwater A Striped bass G Striped bass SB/WB cross	No	No
8. Do you prohibit COMMERCIAL fishing on or near spawning grounds during spawning season? Which species?	Yes[1] A Striped bass	No	No	Yes[2] Amer. shad Hickory shad Blueback herring	No in saltwater, Yes[2] in freshwater A Striped bass G Striped bass SB/WB cross	No	No
9. Do you prohibit COMMERCIAL fishing altogether for any species?	No	Yes Short. sturgeon A Striped bass SB/WB cross	Yes Short sturgeon A Striped bass G Striped bass SB/WB cross	Yes A Striped bass G Striped bass SB/WB cross	Yes Gulf sturgeon Short. sturgeon A Striped bass G Striped bass SB/WB cross	No in saltwater, Yes in freshwater	Yes A Striped bass G Striped bass SB/WB cross
10. Do you regulate COMMERCIAL gear types and require that they be selective for a particular species?	Yes A Striped bass	Yes Atl. sturgeon Amer. shad Hickory shad Blueback herring	Yes Atl. sturgeon Amer. shad Hickory shad	Yes Amer. shad Hickory shad Blueback herring Gulf sturgeon	No	No	No

Table 4.1-45. Questionnaire responses (cont'd.).

QUESTION	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	MISSISSIPPI	LOUISIANA
IV. GOALS AND POLICIES (cont'd)							
11. Do you set minimum fish lengths for legal COMMERCIAL catch?	Yes A striped bass, 12 inches TL	No	No	No	No	No	No
12. Do you limit the number or weight taken by COMMERCIAL fisheries?	No	Yes Blueback herring	No	No	No in saltwater. Yes[2] in freshwater A Striped bass G Striped bass ~~SB/WB cross~~	No	No
13. List those species which provide an annual SPORT harvest.	A striped bass Amer. shad Hickory shad Alewife Blueback herring	A striped bass Amer. shad Hickory shad Blueback herring SB/WB cross	A striped bass Amer. shad Alabama shad Blueback herring Skipjack herring G striped bass SB/WB cross	A striped bass G striped bass Amer. shad Hickory shad Alabama shad SB/WB cross	A striped bass G striped bass Skipjack herring SB/WB cross	A striped bass G striped bass	A Striped bass G Striped bass SB/WB cross
14. List those species managed for SPORT use.	A striped bass Amer shad Hickory shad Alewife Blueback herring	A striped bass SB/WB cross	A striped bass G striped bass Amer. shad Hickory shad SB/WB cross	A striped bass G striped bass Amer. shad Hickory shad Alabama shad SB/WB cross	A striped bass G striped bass SB/WB cross	A striped bass G striped bass	A Striped bass G Striped bass SB/WB cross
15. Do you restrict SPORT fishing effort during spawning season?	No	No	No	Yes[2] A striped bass Amer. shad Hickory shad G Striped bass	No	No	No

Table 4.1-45. Questionnaire responses (cont'd.).

QUESTION	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	MISSISSIPPI	LOUISIANA
IV GOALS AND POLICIES (cont'd)							
16. Do you prohibit SPORT fishing on or near spawning grounds during spawning season?	No	No	No	No	No	No	No
17. Do you prohibit SPORT fishing altogether for any species?	No	No	No	No	Yes[1] Gulf sturgeon	No	No
18. Do you restrict SPORT fishing gear types?	No	No	Yes A Striped bass G Striped bass Amer. shad Alabama shad Skipjack herring SB/WB cross	No	No	No	No
19. Do you restrict or regulate SPORT fishing bait types?	No	No	No	No	No	No	No
20. Do you set minimum fish lengths for legal SPORT catch?	Yes A Striped bass, 12 inches TL	No	Yes[2] A Striped bass	Yes[1] A Striped bass, 15 inches TL	No	Yes	No
21. Do you set creel limits on any of these species? (Creel limit in parenthesis)	Yes[1] A Striped bass (25, [illegible]) (8 inland waters)	Yes A Striped bass (10) SB/WB cross	Yes A Striped bass G Striped bass Amer. shad Hickory shad SB/WB cross	Yes A Striped bass or SB/WB cross (6) Amer. shad (10) G Striped bass	No in saltwater, Yes in freshwater A Striped bass (6) G Striped bass (6) SB/WB cross (6)	Yes A Striped bass G Striped bass	Yes A Striped bass G Striped bass SB/WB cross

Table 4.1-45. Questionnaire responses (cont'd.).

QUESTION:	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	MISSISSIPPI	LOUISIANA
IV. GOALS AND POLICIES (cont'd.)							
22. Do you have NATIVE GROUPS (e.g., Indians) or RESIDENTS in your state to which a portion of the anadromous resource is allocated?	No	No	No	No	No	No	No
V. MITIGATION - ENHANCEMENT							
1. Do you have a formal plan for stocking anadromous fish in your state?	Yes A Striped bass	Yes A Striped bass SB/WB cross	Yes[2] A Striped bass SB/WB cross	Yes A Striped bass G Striped bass (with USFWS) SB/WB cross	Yes A Striped bass G Striped bass SB/WB cross	Yes A Striped bass G Striped bass	Yes A Striped bass G Striped bass SB/WB cross
2. Are you REHABILITATING existing spawning runs to some level through stocking?	Yes[1] A Striped bass	Yes A Striped bass	Yes A Striped bass	Yes[1] A Striped bass	Yes A Striped bass SB/WB cross	Yes A Striped bass G Striped bass	Yes A Striped bass
3. Are you RESTORING spawning runs which no longer exist through stocking?	Yes[1] A Striped bass	No	No	No	Yes A Striped bass SB/WB cross	Yes A Striped bass G Striped bass	Yes A Striped bass
4. Are you CREATING new spawning runs in river systems which appear conducive to anadromous fish?	No	No	No	Yes[1] SB/WB cross	No	Yes A Striped bass G Striped bass	Yes A Striped bass

Table 4.1-45. Questionnaire responses (cont'd.).

QUESTION	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	MISSISSIPPI	LOUISIANA
IV MITIGATION - ENHANCEMENT (cont'd)							
5. Are you presently stocking to manage commercial and sport use of the anadromous fishery at an optimum yield level?	Yes[1] A Striped bass	Yes[1] A Striped bass (sport) SB/WB cross (sport)	No	Yes[1] SB/WB cross (sport)	Yes[2] A Striped bass	Yes A Striped bass G Striped bass	No
6. Have you established, or are you presently establishing, hatcheries to support your stocking efforts?	Yes[1] A Striped bass	Yes A Striped bass SB/WB cross	Yes A Striped bass SB/WB cross	Yes[1] A Striped bass SB/WB cross	Yes A Striped bass SB/WB cross	Yes A Striped bass G Striped bass	Yes A Striped bass
7. Do you support stocking efforts from state-issued commercial and/or sport STAMP REVENUES?	No	No	No	No	No	No	Yes A Striped bass
8. Do you support stocking from only STATE FUNDS?	No	No	No	No	No	No	No
9. Do you support stocking efforts from both STATE and FEDERAL funds?	Yes A Striped bass	Yes A Striped bass SB/WB cross	Yes A Striped bass SB/WB cross	Yes[1] A Striped bass SB/WB cross	Yes A Striped bass SB/WB cross G Striped bass	Yes A Striped bass G Striped bass	Yes A Striped bass
10. Have you constructed fishway facilities?	No	No	No	No	No	No	No
11. Have you attempted to create new spawning sites?	No	No	No	No	No	No	No

Table 4.1-45. Questionnaire responses (cont'd.).

QUESTION:	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	MISSISSIPPI	LOUISIANA
V. MITIGATION - ENHANCEMENT (cont'd)							
12. Have you attempted to increase fish access to present spawning sites by removal of barriers, fallen trees, channelization, etc.?	Yes[1] A Striped bass Amer. shad Hickory shad Alewife Blueback herring	No	No	No	No	No	No
13. Have you attempted to improve or increase nursery areas?	Yes[1] A Striped bass Alewife Blueback herring	No	No	No	Yes[2] Gulf sturgeon Short. sturgeon A Striped bass G Striped bass Alabama shad Skipjack herring SB/WB cross	No	No
14. Do you presently manipulate predator and competitor populations to favor survival of anadromous populations?	No	No	No	No	No	No	No
15. Do you presently control spawning grounds accessibility to sport and commercial fishermen?	Yes[1] A Striped bass Amer. shad Hickory shad Alewife Blueback herring	No	No	Yes[2] Amer. shad Hickory shad Blueback herring (commercial access restricted)	No	No	No

Table 4.1-45. Questionnaire responses (cont'd.).

QUESTION:	NORTH CAROLINA	SOUTH CAROLINA	GEORGIA	FLORIDA	ALABAMA	MISSISSIPPI	LOUISIANA
V. MITIGATION - ENHANCEMENT (cont'd)							
16. Do you presently regulate or control water release from impoundments during spawning season?	Yes[1] A Striped bass Amer. shad Hickory shad Alewife Blueback herring	No (Have agreement with power company)	No	No	No	No	No
17. Does your state presently have an anadromous species management plan?	No	Yes[1] A Striped bass Blueback herring SB/WB cross (plan developed but not formally implemented)	Yes A Striped bass Amer. shad Hickory shad Blueback herring	Yes[1] A Striped bass SB/WB cross	Yes[1] A Striped bass	No	Yes A Striped bass
18. If answer (to #17) is no, are there plans to develop one in the near future?	Yes Atl. sturgeon A Striped bass Amer. shad Hickory shad Alewife Blueback herring	Yes American shad		No[2]	No[2]	Yes A Striped bass G Striped bass	
VI. SPAWNING RUN IDENTIFICATION							
1. Were any of the spawning runs in your state rehabilitated or introduced by STOCKING, LOCKING, construction of FISHWAY FACILITIES, or other method?	Yes A striped bass Amer. shad Alewife Blueback herring	Yes[1] Blueback herring	No	Yes[1] A striped bass G striped bass SB/WB cross	Yes A striped bass SB/WB cross	Yes A striped bass G striped bass	Yes A Striped bass SB/WB cross

Table [illegible]. Status of anadromous fish species, along with the stocked striped bass-white bass hybrid, in river systems within Region 4 based on questionnaire respones to question VI-2. Response from marine representative (S) precedes the response from freshwater representative (F). 0 = probably never present; 1 = increasing; 2 = stable; 3 = declining; 4 = threatened; 5 = no longer present; 6 = unknown.

RIVER SYSTEM	ATLANTIC STURGEON S/F	GULF STURGEON S/F	SHORTNOSE STURGEON S/F	STRIPED BASS (ATLANTIC) S/F	STRIPED BASS (GULF) S/F	STRIPED/WHITE BASS HYBRID S/F	AMERICAN SHAD S/F	HICKORY SHAD S/F	ALABAMA SHAD S/F	ALEWIFE S/F	BLUEBACK HERRING S/F	SKIPJACK HERRING S/F
NORTH CAROLINA												
Currituck Sound			5/							3/	3/	
Albemarle Sound	/3		5/4	3/3			3/3	/3		3/3	3/3	
North R.			5/							3/	3/	
Pasquotank R.			5/							3/	3/	
Little R.			5/							3/	3/	
Perquimans R.			5/							3/	3/	
Yeopim R.			5/							3/	3/	
Chowan R.	2-3/3		5/4	3/0			3/3	2-3/3		3/3	3/3	
Meherrin R.			5/	2-3/			3/	2-3/		3/	3/	
Roanoke R.	2-3/3		5/4	3/3			3/3	2-3/3		3/3	3/3	
Cashie R.			5/				3/	2-3/		3/	3/	
Scuppernong R.			5/							3/	3/	
Alligator R.			5/							3/	3/	
Pungo R.			[illegible]							6/	6/	

Table 4.1-46. Species status (cont'd.).

	ATLANTIC STURGEON	GULF STURGEON	SHORTNOSE STURGEON	STRIPED BASS (ATLANTIC)	STRIPED BASS (GULF)	STRIPED/WHITE BASS HYBRID	AMERICAN SHAD	HICKORY SHAD	ALABAMA SHAD	ALEWIFE	BLUEBACK HERRING	SKIPJACK HERRING
	S/F	S/F	S/F	S/F	S/F	S/F	S/F	S/F	S/F	S/F	S/F	S/F
NORTH CAROLINA (cont'd.)												
Pamlico R.	2-3/		5/	1/						6/	6/	
Tar R.	2-3/3		5/4	1/1			3/3	2-3/3		2-3/3	2-3/3	
Neuse R.	2-3/3		5/4	2/3			3/3	2-3/3		2-3/3	2-3/3	
Trent R.			5/				3/	2-3/		2-3/	2-3/	
North R.			5/							6/	6/	
Newport R.			5/							6/	6/	
White Oak R.			5/	3/			6/				6/	
New R.			5/	4-5/			4/	4/		4/	4/	
Cape Fear R.	2-3/3		5/4	2-3/3			3/3	2-3/3		2-3/3	2-3/3	
Northeast Cape Fear	2-3/3		5/4	2-3/3			3/3	/3		2-3/3	2-3/3	
Black R.			5/				6/			6/	6/	
Pee Dee R.	/3		/4	/3			/3	/3		/3	/3	
SOUTH CAROLINA												
Waccamaw R.	6/2		4/6	6/2		/0	2/2	6/2			2/2	
Little Pee Dee R.	2/		4/	2/		/0	/2	/2			/6	
Great Pee Dee R.	6/2		6/4	6/2		/0	2/2	6/2			2/2	

Table 4.1-46. Species status (cont'd.).

RIVER SYSTEM	ATLANTIC STURGEON S/F	GULF STURGEON S/F	SHORTNOSE STURGEON S/F	STRIPED BASS (ATLANTIC) S/F	STRIPED BASS (GULF) S/F	STRIPED/WHITE BASS HYBRID S/F	AMERICAN SHAD S/F	HICKORY SHAD S/F	ALABAMA SHAD S/F	ALEWIFE S/F	BLUEBACK HERRING S/F	SKIPJACK HERRING S/F
Black R.	6/2		6/4	6/2		/0	2/2	6/2			2/2	
Santee R.	6/2		6/4	6/2		/0	3/2	6/2			2/2	
Cooper R.	6/2		6/4	6/2		/6	2/2	6/2			2/1	
Ashley R.	6/2		6/4	6/2		/0	2/2	6/2			2/6	
Edisto R.	6/2		6/4	6/2		/0	3/2	6/2			2/6	
Ashepoo R.	6/2		6/4	6/2		/0	2/2	6/2			2/6	
Combahee R.	6/2		6/4	6/2		/0	2/2	6/2			2/6	
Sampit R.	6/2		6/4	6/2		/0	1/2	6/2			2/2	
Salkehatchie R.	/2		[illegible]	[illegible]		/0	/2	/2			/6	
Savannah R.	6/2		6/4	6/2		6/0	2/2	6/2			2/6	
Lynches R.	6/		6/	6/		6/	2/	2/			2/	
GEORGIA												
Savannah R.	6/6		4/4	3/6	0/0	6/1	6/6	6/6	0/0	0/0	6/6	6/0
Ogeechee R.	6/6		4/4	3/6	0/0	0/0	3/6	6/6	0/0	0/0	6/6	6/0
Altamaha R.	6/6		4/4	3/6	0/0	6/0	6/6	6/6	0/0	0/0	6/6	6/0
Oconee R.	/6		/4	/6	/6	/0	/6	/6	/0	/0	/6	/0
Satilla R.	6/		4/4	3/6	0/0	0/0	3/6	6/6	/0	0/0	6/6	6/0

Table 4.1-46. Species status (cont'd.).

	ATLANTIC STURGEON S/F	GULF STURGEON S/F	SHORTNOSE STURGEON S/F	STRIPED BASS (ATLANTIC) S/F	STRIPED BASS (GULF) S/F	STRIPED/WHITE BASS HYBRID S/F	AMERICAN SHAD S/F	HICKORY SHAD S/F	ALABAMA SHAD S/F	ALEWIFE S/F	BLUEBACK HERRING S/F	SKIPJACK HERRING S/F
GEORGIA (cont'd.)												
Ocmulgee R.	/6		/4	/6	/0	/1	/6	/6	/0	/0	/6	/0
St. Marys R.	6/		4/4	3/6	0/0	0/0	3/6	6/6	0/0	0/0	6/6	6/0
Chattahoochee R.		/6	/0	/1	/1	/1	/0	/0	/6	/0	/0	/2
Flint R.		/6	/0	/1	/1	/1	/0	/0	/6	/0	/0	/2
FLORIDA (East Coast)												
St. Marys R.	4/2		/6	3/2		/0	3/2	6/6	/0		6/	
Nassau R.	0/2		/6	3/2		/0	6/2	6/6	/0		6/	
St. Johns R.	3/3		/4	6/1		/0	3/2	3/6	/0		3/	
Pellicer Cr.	0/			0/			3/	6/			6/	
Moultrie Cr.	0/			0/			0/	0/			0/	
Tomoka R.	0/			0/			3/	3/			3/	
FLORIDA (West Coast)												
Hillsborough R.	0/	5/	0/	0/	0/		0/	0/	0/		0/	
Suwannee R.	0/	2/	0/	0/	0/		0/	0/	0/		0/	
Apalachicola R.	0/0	4/3	0/6	0/	4/2	6/1	0/0	0/6	3/2		0/	
Ochlockonee R.		/5	/6	/1		/0	/0	/6	/0			
Escambia R.						/1						

Table 4.1-46. Species status (cont'd).

	ATLANTIC STURGEON S/F	GULF STURGEON S/F	SHORTNOSE STURGEON S/F	STRIPED BASS (ATLANTIC) S/F	STRIPED BASS (GULF) S/F	STRIPED/WHITE BASS HYBRID S/F	AMERICAN SHAD S/F	HICKORY SHAD S/F	ALABAMA SHAD S/F	ALEWIFE S/F	BLUEBACK HERRING S/F	SKIPJACK HERRING S/F
ALABAMA												
Alabama R.		6/5	6/	1/1	3/5	1/1	0/	0/	3/2	0/	0/	6/2
Tombigbee R.		6/5	6/	1/	3/	1/	0/	0/	3/2	0/	0/	6/2
Perdido R.		6/	6/	1/	6/	0/	0/	0/	6/	0/	0/	6/
Bon Secour R.		6/	6/	1/	6/	6/	0/	0/	6/	0/	0/	6/
Fish R.		6/	6/	1/	6/	6/	0/	0/	6/	0/	0/	6/
Magnolia R.		6/	6/	1/	6/	6/	0/	0/	6/	0/	0/	6/
Dog. R.		6/	6/	1/	6/	6/	0/	0/	6/	0/	0/	6/
Fowl R.		6/	6/	1/	6/	6/	0/	0/	6/	0/	0/	6/
Tennessee R.		/5		/1	/0	/1			/2			
Chattahoochee R.						/1			/2			/2
Coosa R.		/5		/1	/5	/1			/3			/3
Tallapoosa R.		/5		/1	/5	/1			/3			/3
MISSISSIPPI												
Pascagoula R.		6			6							
Tchouticabouffa R.		6		1	6							
Biloxi R.		6		1	6							
Wolf R.		6		1	6							

Table 4.1-46. Species status (cont'd.).

	ATLANTIC STURGEON S/F	GULF STURGEON S/F	SHORTNOSE STURGEON S/F	STRIPED BASS (ATLANTIC) S/F	STRIPED BASS (GULF) S/F	STRIPED/WHITE BASS HYBRID S/F	AMERICAN SHAD S/F	HICKORY SHAD S/F	ALABAMA SHAD S/F	ALEWIFE S/F	BLUEBACK HERRING S/F	SKIPJACK HERRING S/F
MISSISSIPPI (cont'd.)												
Jourdan R.		6		1	6							
Pearl R.		6		1	6							
LOUISIANA												
Pearl R.		6	0	1	6	1	0	0	6	0	0	2
Bayou LaCombe		6	0	1	6	1	0	0	6	0	0	2
Tchefuncte R.		6	0	1	6	1	0	0	6	0	0	2
Tangipahoa R.		6	0	1	6	1	0	0	6	0	0	2
Tickfaw R.		6	0	1	6	1	0	0	6	0	0	2
Amite R.		6	0	1	6	1	0	0	6	0	0	2
Mississippi R.		6	0	1	6	1	0	0	6	0	0	2
Atchafalaya R.		6	0	1	0	1	0	0	6	0	0	2
Vermillion R.		6	0	6	0	6	0	0	6	0	0	2
Mermentau R.		6	0	1	0	0	0	0	6	0	0	2
Calcasieu R.		6	0	1	0	0	0	0	6	0	0	2
Sabine R.		6	0	1	0	1	0	0	6	0	0	2

Table 4.1-47 Factors possibly important or very important in contributing to the decline of certain populations of anadromous fish stocks in river systems within Region 4 based on questionnaire reponses to question II. S = response by marine representative; F = response by freshwater representative; C = responses by other agenices.

NORTH CAROLINA

CURRITUCK SOUND

None or inadequate information (S)

ALBEMARLE SOUND TRIBUTARIES

Channelization (F)
Dredge and fill proejcts (F)
Bulkheading (F)
Chemical pollution (F)
Low oxygen levels (F)
Sewerage outfalls (F)
Reduction in spawning habitat (F)
Reduction in nursery areas (F)
Poor food availability (F)
Spawning areas too accessible to fishermen (F)
Poor water quality (F)

CHOWAN RIVER

Channelization (F)
Dredge and fill projects (F)
Bulkheading (F)
Industrial water intakes (C)
Location of industrial discharges (FC)
Chemical pollution (FS)
Low oxygen levels (FSC)
Sewerage outfalls (FC)
Reduced freshwater input to estuaries (C)
Reduction in spawning habitat (FC)
Reduction in nursery areas (FC)
Poor food availability (F)
Spawning areas too accessible to fishermen (F)
Poor water quality (FSC)
Turbidity (F)

ROANOKE RIVER

Channelization (F)
Dredge and fill projects (F)
Dams and impoundments (FC)
Industrial water intakes (FC)
Location of industrial discharges (FC)
Chemical pollution (F)
Turbidity (F)
Low oxygen levels (FSC)
Sewerage outfalls (FC)
Inadequate control of water release from dams (FSC)
Reduction in spawning habitats (F)
Reduction in nursery areas (F)
Poor food availability (F)
Spawning areas too accessible to fishermen (FC)
Poor water quality (FSC)

OTHER ALBEMARLE AREA RIVERS

Poor water quality (S)

ALBEMARLE SOUND

Low oxygen levels (S)
Poor water quality (S)

PUNGO RIVER

None or inadequate information (S)

Table 4.1-47. Important factors (cont'd.).

TAR RIVER

- Channelization (F)
- Dams and impoundments (F)
- Industrial water intakes (F)
- Location of industrial discharges (F)
- Chemical pollution (F)
- Turbidity (F)
- Low oxygen levels (F)
- Sewerage outfalls (F)
- Inadequate control of water release from dams (F)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)
- Spawning areas too accessible to fishermen (F)
- Poor water quality (F)

PAMLICO RIVER

- None or inadequate information (S)

NEUSE RIVER

- Channelization (F)
- Dams and impoundments (FC)
- Industrial water intakes (FC)
- Location of industrial discharges (FC)
- Chemical pollution (F)
- Turbidity (F)
- Low oxygen levels (FC)
- Sewerage outfalls (FC)
- Inadequate fishway facilities (C)
- Inadequate control of water release from dams (F)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)
- Poor food availability (F)
- Spawning areas too accessible to fishermen (F)
- Poor water quality (FC)
- Locks and barriers (C)

TRENT RIVER

- None or inadequate information (S)

WHITE OAK RIVER

- None or inadequate information (S)

NEW RIVER

- Channelization (S)
- Reduction in spawning habitats (S)
- Reduction in nursery areas (S)

CAPE FEAR RIVER

- Channelization (FC)
- Dams and impoundments (F)
- Industrial water intakes (FC)
- Location of industrial discharges (FC)
- Locks and barriers (C)
- Chemical pollution (F)
- Turbidity (F)
- Low oxygen levels (F)
- Sewerage outfalls (FC)
- Inadequate fishway facilities (C)
- Inadequate control of water release from dams (F)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)
- Poor food availability (F)
- Spawning areas too accessible to fishermen (F)
- Poor water quality (F)

NORTHEAST CAPE FEAR RIVER

- Channelization (F)
- Chemical pollution (F)
- Turbidity (F)
- Low oxygen levels (F)
- Sewerage outfalls (F)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)
- Poor food availability (F)
- Spawning areas too accessible to fishermen (F)
- Poor water quality (F)

NORTH RIVER

None or inadequate information (S)

NEWPORT RIVER

None or inadequate information (S)

PEE DEE RIVER

[illegible]s and impoundments (F)
Industrial water intakes (F)
Location of industrial discharges (F)
Chemical pollution (F)
Turbidity (F)
Low oxygen levels (F)
Sewerage outfalls (F)
Inadequate control of water release from dams (F)
Poor water quality (F)

SOUTH CAROLINA

WACCAMAW RIVER

None or inadequate information (S)

PEE DEE RIVER

Dams and impoundments (S)
Inadequate fishway facilities (S)
Reduction in spawning habitats (S)
Reduction in nursery areas (S)

BLACK RIVER

None or inadequate information (S)

SAMPIT RIVER

[illegible]ical pollution (S)
Poor water quality (S)

SANTEE RIVER

Dams and impoundments (S)
Inadequate fishway facilities (S)
[illegible] habitats [illegible]
Reduction in nursery areas (S)

COOPER RIVER

Dams and impoundments (S)
Reduction in spawning habitats (S)
Reduction in nursery areas (S)

ASHLEY RIVER

None or inadequate information (S)

EDISTO RIVER

None or inadequate information (S)

ASHEPOO RIVER

None or inadequate information (S)

COMBAHEE RIVER

None or inadequate information (S)

LYNCHES RIVER

None or inadequate information (S)

SAVANNAH RIVER

Dams and impoundments (S)
Inadequate fishway facilities (S)
Reduction in spawning habitat (S)
Reduction in nursery areas (S)
Poor water quality (S)

GEORGIA

[illegible]NAH RIVER

Dredge and fill projects (S)
Dams and impoundments (S)
Location of industrial discharges (S)
Chemical pollution (S)
[illegible] habitats [illegible]

Table 4.1-47. Important factors (cont'd.).

SAVANNAH RIVER (cont'd.)

Reduction in nursery areas (S)
Poor food availability (S)
Poor water quality (S)

OGEECHEE RIVER

Channelization (S)
Dredge and fill projects (S)
Dams and impoundments (S)
Location of industrial discharges (S)
Reduction in spawning habitats (S)
Reduction in nursery areas (S)
Poor food availability (S)
Poor water quality (S)

ALTAMAHA RIVER

Channelization (S)
Dredge and fill projects (S)
Dams and impoundments (S)
Location of industrial discharges (S)
Chemical pollution (S)
Reduction in spawning habitats (S)
Reduction in nursery areas (S)
Poor food availability (S)
Poor water quality (S)

SATILLA RIVER

Channelization (S)
Dredge and fill projects (S)
Dams and impoundments (S)
Location of industrial discharges (S)
Reduction in spawning habitats (S)
Reduction in nursery areas (S)
Poor food availability (S)
Poor water quality (S)

ST. MARYS RIVER

Dredge and fill projects (S)
Dams and impoundments (S)
Location of industrial discharges (S)
Reduction in spawning habitats (S)
uction in nursery areas (S)
Poor food availability (S)
Poor water quality (S)

APALACHICOLA RIVER

Dams and impoundments (F)
Reduction in spawning habitats (F)

FLORIDA (Atlantic coast)

ST. MARYS RIVER

Channelization (S)
Bulkheading (F)
Location of industrial discharges (F)
Chemical pollution (FS)
Reduction in nursery areas (F)
Poor water quality (F)
Industrial water intakes (F)

NASSAU RIVER

Bulkheading (F)
Industrial water intakes (F)
Location of industrial discharges (F)
Chemical pollution (F)
Reduction in nursery areas (F)
Poor water quality (F)

ST. JOHNS RIVER

Channelization (FS)
Dredge and fill projects (FS)
Bulkheading (F)
Dams and impoundments (F)
Industrial water intakes (S)
Location of industrial discharges (FS)
Agricultural drainage (F)
Chemical pollution (FS)
Thermal effluents (S)
Low oxygen levels (FS)
Sewerage outfalls (F)
Agricultural and domestic non-point source pollution (S)
Reduced freshwater input to estuaries (S)
Reduction in spawning habitats (FS)
Reduction in nursery areas (FS)

Table 4.1-47. Important factors (cont'd.)

ST. JOHNS RIVER (cont.d)

- Spawning areas too accessible to fishermen (S)
- Poor water quality (FS)
- Overfishing (S)

TOMOKA RIVER

- Chemical pollution (S)
- Agricultural and domestic non-point source pollutants (S)
- Poor water quality (S)

FLORIDA (Gulf coast)

HILLSBOROUGH RIVER

- Dams and impoundments (S)
- Location of industrial discharges (S)
- Sewerage outfalls (S)
- Inadequate fishway facilities (S)
- Reduction in spawning habitats (S)
- Reduction in nursery areas (S)
- Poor water quality (S)
- Agricultural and domestic non-[illegible]t source pollutants
- Overfishing (S)
- [illegible]osed phosphate strip-mining (S)

SUWANNEE RIVER

- Location of industrial discharges (S)
- Agricultural and domestic non-point source pollutants
- Proposed phosphate strip-mining (S)

OCHLOCKONEE RIVER

- [illegible]r inadequate information (S)

[illegible]

- Channelization (FS)
- Dredge and fill projects (F)
- Bulkheading (F)
- Dams and impoundments (F)
- [illegible] (FS)
- Chemical pollution (F)
- Turbidity (F)
- Sewerage outfalls (FS)
- Inadequate fishway facilities (
- Reduction in spawning habitats
- Reduction in nursery areas (S)
- Poor water quality (F)
- Overfishing (S)

ALABAMA

PERDIDO RIVER

- Location of industrial discharg (S)
- Chemical pollution (S)
- Low oxygen levels (S)
- Poor water quality (S)

ALABAMA RIVER

- Bulkheading (F)
- Dams and impoundments (FS)
- Location of industrial discharg (FS)
- Chemical pollution (FS)
- Low oxygen levels (S)
- Inadequate fishway facilities (
- Inadequate control of water release from dams (FS)
- [illegible] in spawning habitats (F)
- Reduction in nursery areas (F)
- Poor water quality (S)

TENNESSEE

- Bulkheading ([illegible]
- Dams and impoundments (F)
- Location of industrial discharg [illegible]
- Chemical pollution (F)
- [illegible]
- [illegible]ase from dams (F)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)

Table 4.1-47. Important factors (cont'd.).

TOMBIGBEE RIVER

- Dams and impoundments (FS)
- Location of industrial discharges (FS)
- Chemical pollution (FS)
- Low oxygen levels (S)
- Inadequate fishway facilities (FS)
- Inadequate control of water release from dams (FS)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)
- Poor water quality (FS)

COOSA RIVER

- Dams and impoundments (F)
- Location of industrial discharges (F)
- Chemical pollution (F)
- Inadequate fishway facilities (F)
- Inadequate control of water release from dams (F)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)
- Poor water quality (F)

TALLAPOOSA RIVER

- Dams and impoundments (F)
- Location of industrial discharges (F)
- Chemical pollution (F)
- Inadequate fishway facilities (F)
- Inadequate control of water release from dams (F)
- Reduction in spawning habitats (F)
- Reduction in nursery areas (F)
- Poor water quality (F)

FISH RIVER

- None or inadequate information (S)

MAGNOLIA RIVER

- None or inadequate information (S)

BON SECOUR RIVER

- Location of industrial discharges (S)

DOG RIVER

- None or inadequate information (S)

FOWL RIVER

- None or inadequate information (S)

MISSISSIPPI

PASCAGOULA RIVER

- Inadequate information

TCHOUTICABOUFFA RIVER

- Inadequate information

BILOXI RIVER

- Inadequate information

WOLF RIVER

- Inadequate information

JOURDAN RIVER

- Inadequate information

PEARL RIVER

- Inadequate information

Table 4.1-47. Important factors (cont'd.).

LOUISIANA	CALCASIEU RIVER
PEARL RIVER	Inadequate information
Channelization Dams and impoundments	SABINE RIVER
BAYOU LaCOMBE	Inadequate information
Channelization Dams and impoundments	
TCHEFUNCTE RIVER	
Channelization	
TANGIPAHOA RIVER	
Channelization	
TICKFAW RIVER	
Channelization	
AMITE RIVER	
Channelization	
MISSISSIPPI RIVER	
Channelization Dredge and fill projects	
ATCHAFALAYA RIVER	
Channelization Dredge and fill projects	
VERMILLION RIVER	
Inadequate information	
MERMENTAU RIVER	
Channelization Dredge and fill projects Dams and impoundments	

DATE DUE

JUL 0 7 2000			
AUG 3 1 2000			
RT/CO SEP 1 2 '00			
IL: 5062040			
R. Lemonds			
Due: 6/8/04			

RETURNED